



# RCAAS

中央研究院  
ACADEMIA SINICA

應用科學研究中心

Research Center for **APPLIED SCIENCES**

以應用為導向的研究與技術發展機構

綠色科技專題中心



智慧生物工程專題中心



量子光電專題中心



## 任 務

運用最尖端、新穎的科技成果，進行跨領域的基礎科學與應用研究，以期達到在地影響力及國際卓越。

應用科學研究中心包含三大專題中心：智慧生物工程、綠色科技及量子光電。

## 合作研究協定

- 2012 ● 國立交通大學
  - 國立東華大學 | 材料科學與工程學系、物理學系
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- 2014 ● 長庚大學工學院
  - 國立陽明大學生物醫學暨工程學院
  - 日本北海道大學電子科學研究所
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- 2015 ● 國立成功大學光電科學與工程學系
- 2016 ● 國立清華大學材料科學工程學系
- 2020 ● 國立臺東大學應用科學系
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  - 國立成功大學智慧半導體及永續製造學院半導體製程學位學程
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## 目 錄

中研院應用科學研究中心介紹	2
合作研究協定	2
菁英人才共同培育協定	3
學術諮詢委員名單	4
研究領域介紹	5
智慧生物工程專題中心	5
綠色科技專題中心	7
量子光電專題中心	9
研究人員資料	10
智慧生物工程	林鈺容 33
董奕鍾 13	謝東翰 35
魏培坤 15	謝書宜 37
鄭邈言 17	綠色科技
楊富量 19	朱治偉 41
陳培菱 21	包淳偉 43
林榮信 23	郭宗枋 45
李超煌 25	張允崇 47
薛景中 27	程育人 49
郭志禹 29	呂宥蓉 51
陳壁彰 31	方牧懷 53
量子光電	
張文豪 57	
施閔雄 59	
關肇正 61	
林時彥 63	
張書維 65	
陳 祺 67	
陳俞辰 69	
重要獎項榮譽	71
中心核心設施	72
行政人員	74

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- 長庚大學工學院
- 國立清華大學腦科學研究中心
- 國立清華大學生命科學院
- 國立成功大學 光電科學與工程學系
- 國立陽明交通大學 材料科學與工程學系
- 國立臺灣大學 工學院綠色永續材料與精密元件博士學位學程
- 國立臺灣大學 化學系
- 國立陽明交通大學生物科技學院
- 國立臺灣大學工學院應用力學研究所
- 國立中興大學電機工程學系
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智慧生物工程專題中心是一個致力於生物醫學工程的頂尖研究單位。我們的專題中心致力於透過最先進的感測、成像、表徵量測和製造技術，改變生物醫學應用的方向。我們專題中心旨在透過利用尖端技術和合作創新來應對迫切的基礎生物科學和臨床挑戰。

## 願景與使命

我們的使命是推動生物技術和臨床應用的重大進步，專注於具有轉型潛力的創新解決方案。憑藉一支堅實的專家團隊和戰略合作夥伴，我們致力於突破現有醫療技術的界限，創造對醫療保健有影響力且可持續的技術。

## 我們的團隊與合作精神

本專題中心由十一位研究人員組成—董奕鍾博士、陳培菱博士、魏培坤博士、鄭鄧言博士、楊富量博士、李超煌博士、林榮信博士、薛景中博士、郭志禹博士、陳壁彰博士和林鈺容博士—專題中心還包括兩位研究技師，謝東翰博士和謝書宜博士。我們團隊的專業知識涵蓋了生物工程的全部範疇，從分子生物學到奈米製造技術。這種多樣的專業知識確保了我們研究項目的全面性和多學科性。合作是我們的關鍵理念，本專題中心與中央研究院生命科學同仁及台灣眾多醫學院所都有著緊密的聯繫，促使學術研究與實際應用的無縫整合。

## 研究重點與策略性計劃

我們的研究分為三個主要領域：

**先進成像與感測技術**：我們在開發如層光擴張顯微術這樣的精密成像方法上是該領域的領導者，該技術提供與電子顯微鏡相當的分辨率，並應用先進的質譜技術研究複雜的生物材料。

**生物工程中的人工智慧**：我們中心已開發突破性的人工智慧應用，包括一款獲得國家新創獎的非侵入式血糖計。我們還使用人工智慧增強生物分子交互作用分析和藥物發現的計算方法。此外，我們也運用人工智慧技術來提高偵測技術的靈敏度與三維影像技術的分析速度及準確度。

**創新藥物傳遞系統**：我們正在開創新的藥物傳遞方法，包括用於控制釋放治療化合物的水凝膠系統，提供治療慢性疾病如癌症與肥胖的新方法。

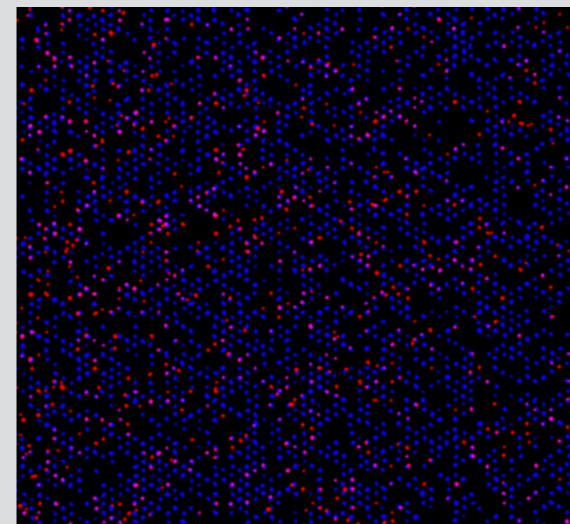
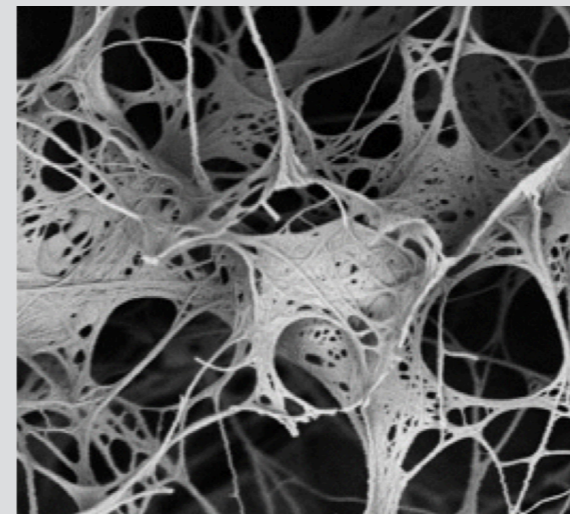
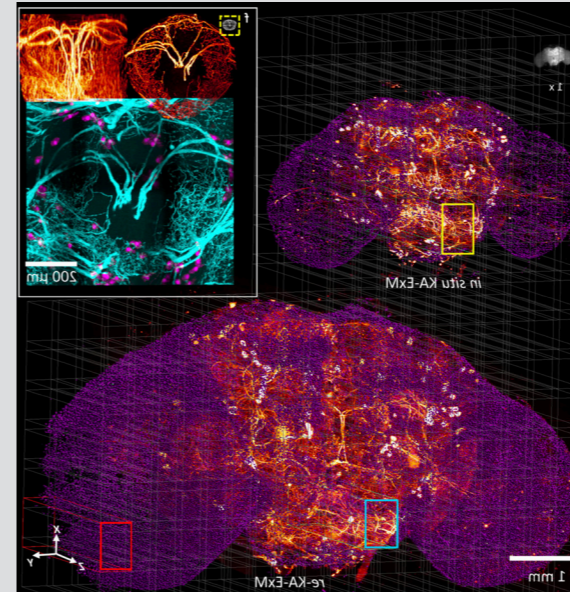
## 主軸研究計劃

為了促進我們主要研究員之間能更深入的合作與創新，我們建立了主軸研究計劃，專注於兩個關鍵議題：

**建立自動化智慧生物實驗室**：本計畫旨在建立一套自動化且智慧化的生物實驗平台，以優化藥物於進入動物實驗與臨床試驗前的早期發現與測試流程。該平台整合人工智慧驅動的虛擬篩選、自動化學合成技術、高靈敏度生物感測系統，以及病患衍生之細胞與類器官模型，能高效率地進行藥物候選化合物的篩選、合成與生物活性評估。

**跨尺度多模組生醫影像技術發展與應用**：本計畫中，我們發展先進生物材料與高解析度之單分子影像技術，以提升生醫診斷與治療的精準度與效率。透過導入體積電子顯微鏡與次奈米等級光學顯微鏡等尖端儀器，建構穩固且高效的研究平台，加速技術創新與臨床應用的轉譯進程。本計畫亦將與醫療機構及國際合作夥伴密切合作，強化臺灣生醫產業的國際競爭力，並致力於建立具全球領導地位的生醫影像研究重鎮。

智慧生物工程主題中心致力於開發突破性技術和促進合作項目，使我們能夠引領生物醫學的下一波進展。隨著我們繼續探索和擴展生物工程的前沿，我們希望能與各領域專家學者，一同創造能夠重新定義醫療技術和醫療保健標準的革命性解決方案。





量子光電專題中心主要目標在於發展應用於光量子技術的關鍵材料與元件。本專題中心整合應科中心原有的研究強項，包含材料生長、光譜量測、元件製程以及理論分析，同時亦與國內外先進研究團隊建立合作，藉此槓桿先進技術以期突破應用於光量子技術之材料與元件的技術瓶頸。目前本專題中心有七位核心成員，包含：張文豪、施閔雄、林時彥、張書維、關肇正、陳祺和陳俞辰。

## 主要研究方向

本專題中心研究領域包含：開發量子光源以及單光子偵測器、探索室溫量子系統應用於自旋操控與量子感測、奈米光子結構設計與製作以及發展新材料與元件技術；期許未來可以在光量子運算與量子通訊應用達成重要的技術突破。

## 主軸計劃

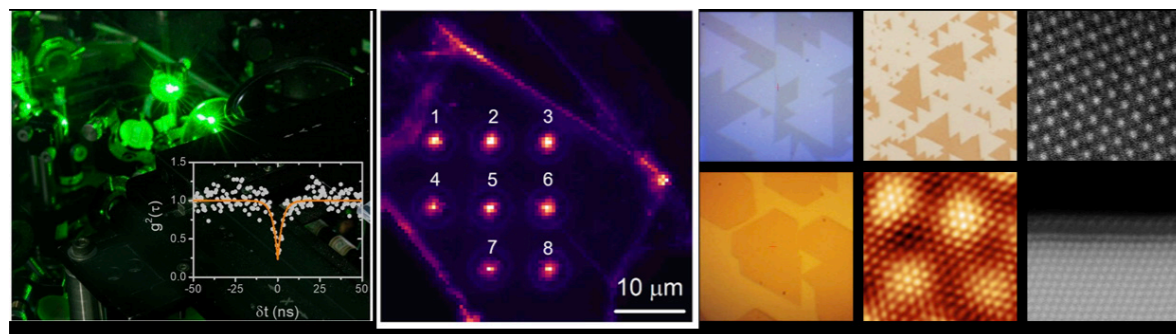
### 1. 提升量子光電元件效率及光量子晶片技術開發

計畫摘要：

量子光電元件，包含單光子光源與單光子偵測器，結合操控光子的光量子晶片，是量子通訊以及光量子運算的關鍵元件與技術。本計畫擬開發之關鍵技術包含：(1) 通訊波段高效率單光子光源；(2) 紅外線超導體單光子偵測器；(3) 量子光電晶片。本計畫擬透過光學共振腔設計，理論模擬計算最佳結構，提升單光子光源與偵測器的效率，達到更高的光子不可分變性，提升糾纏光子對保真度，優化單光子偵測靈敏度與響應速度。開發量子光電晶片技術，整合單光子光源與偵測器，達成光量子態控制與讀取。此外，本計畫也將透過新材料研發 (SiO<sub>2</sub>/SiN、hBN、SiC)，開發通訊波段室溫操作的單光子光源。

預期成果：

提升單光子光源與單光子偵測器效率，開發量子光電晶片，並以新穎材料實現室溫下通訊波段的單光子光源。



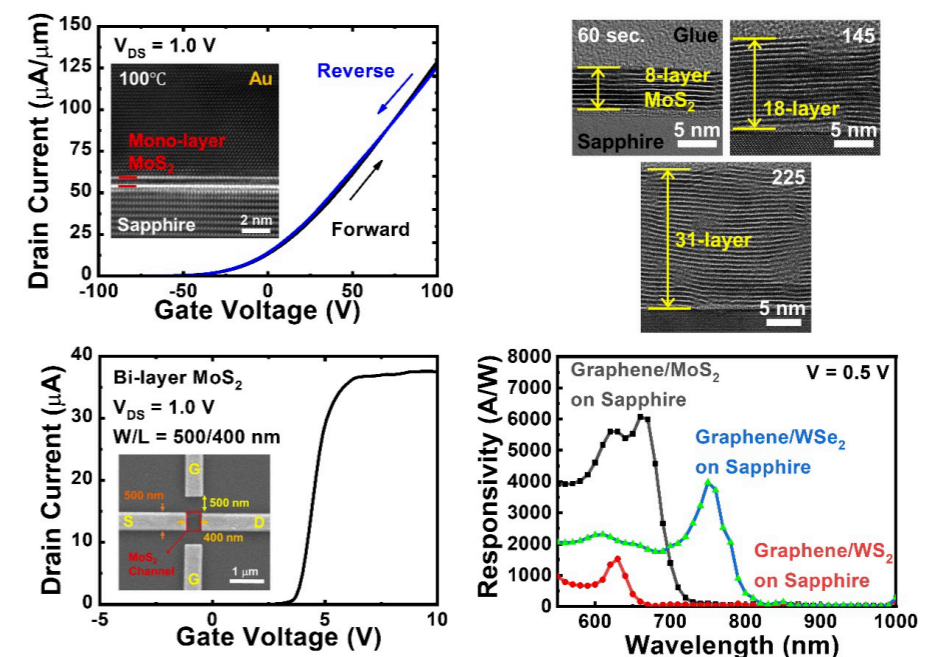
### 2. 二維材料之電子與光電元件技術開發

計畫摘要：

二維材料在新世代電子元件與光電元件具有廣泛的應用，但也存在許多瓶頸。本團隊已具備開發高效能二維電晶體技術，包含以少數層 MoS<sub>2</sub> 為通道材料，在小線寬並搭配鈍化層的元件可達 100 μA/μm 汲極電流以及 >100 cm<sup>2</sup>·V<sup>-1</sup>·s<sup>-1</sup> 的載子遷移率。基於過去累積的元件技術，本計畫將進一步開發 WSe<sub>2</sub> 電晶體元件技術。由於環境對 WSe<sub>2</sub> 材料影響較為顯著，元件效能仍待提升。本計畫將透過改善材料品質與優化製程，目標實現場效遷移率達 10 cm<sup>2</sup>·V<sup>-1</sup>·s<sup>-1</sup> 的 WSe<sub>2</sub> 電晶體。在光電元件方面，本團隊已開發出大面積多層 MoS<sub>2</sub> 薄膜成長技術作為光吸收層，並以單層石墨烯作為載子傳輸層，實現具備高響應度與短響應時間的光偵測器。本年度目標擬將二維材料與傳統半導體整合，開發異質維度光偵測器，透過二維材料短載子遷移時間以及傳統半導體的多樣能隙範圍，在室溫下實現長波長光偵測。此外，二維材料具有超快載子反應速度，搭配其原子層厚度可應用於積體光學晶片中之高速光調變元件。本計畫擬將二維材料與微型光學奈米共振腔結合，使激子和共振腔耦合，並透過外加電壓調控共振腔發光強度，實現高速二維半導體光調變元件，應用於未來積體光學晶片與量子光電晶片。

預期成果：

達成高性能二維 WSe<sub>2</sub> 電晶體元件，載子遷移率達 10 cm<sup>2</sup>·V<sup>-1</sup>·s<sup>-1</sup>；開發異維度光偵測器，偵測波段 > 1.55 μm，響應時間 < 10 ms；開發二維半導體光調變元件，應用於未來積體光學晶片與量子光電晶片。





# 智慧生物工程專題中心

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## 個人簡介

董奕鍾博士現任中央研究院應用科學研究中心研究員，自 2009 年加入中央研究院起致力於跨領域生醫研究。在加入中央研究院應用科學研究中心之前，董博士於美國密西根大學安娜堡分校生物醫學工程學系擔任博士後研究員 (2006–2009)，並於 2005 年獲得該校機械工程博士學位。董博士的研究貢獻廣受國際肯定，榮獲多項學術殊榮，包括 2020–2022 年度全球前 2% 頂尖科學家 (單年度影響力)、2018 年科技部傑出年輕學者研究計畫、2016 年中央研究院前瞻計畫，以及 2014 年科技部吳大猷紀念獎。此外，他於 2016 年獲選為英國皇家化學學會 (Royal Society of Chemistry, RSC) 分析領域前 10% 高被引作者。董博士的研究專注於微流體細胞培養與分析、生醫儀器開發、以及先進微 / 奈米製造技術以推動生醫科技創新。他亦與國內外頂尖醫院及機構，如美國俄亥俄州立大學及波士頓大學，建立合作夥伴關係，推動生醫研究發展。目前，其實驗室正積極研發自動化與智慧化生醫儀器，以提升生醫研究效能，特別聚焦於癌症與神經科學相關議題。

## 代表著作

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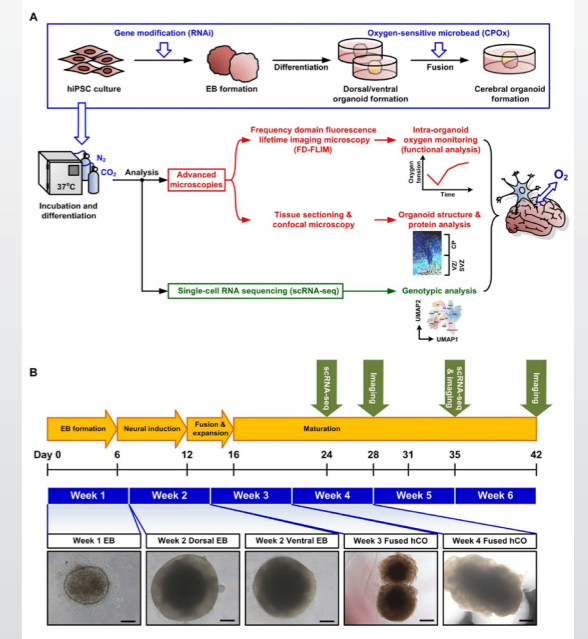
## 研究重點

### Shaping early neural development by timed elevated tissue oxygen tension: Insights from multiomic analysis on human cerebral organoids

Yuan-Hsuan Liu, Meng-Ting Chung, His-Chieh, Lin, Tse-Ang, Lee, Ya-Jen Cheng, Chien-Chang Huang, Hsiao-Mei Wu,\* and Yi-Chung Tung\*

Academic Sinica, Research Center for Applied Sciences  
Science Advances 2025, DOI: 10.1126/sciadv.ado1164

Oxygen is critical for early brain development, especially before full vascularization, but has been understudied due to technical challenges. This study uses human cerebral organoids with advanced microscopies and single-cell RNA sequencing to monitor tissue oxygen during neurodevelopment. A key window between weeks 4 and 6 shows elevated intra-organoid oxygen, altered energy metabolism, and rapid neurogenesis. This oxygen increase is suppressed by hypoxia or neuroglobin gene silencing. The findings reveal oxygen's functional, genotypic, and proteomic roles in early neurogenesis and highlight the importance of timed oxygen elevation. The study also implicates neuroglobin in neural development, offering insights relevant to neurodegenerative diseases and potential therapeutic strategies.

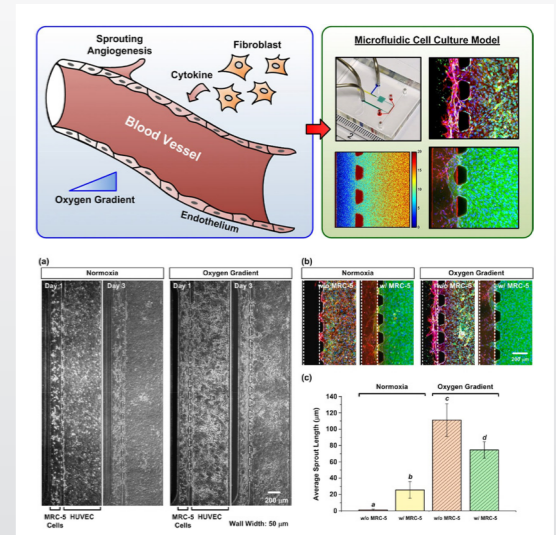


### Studying sprouting angiogenesis under combination of oxygen gradients and co-culture of fibroblasts using microfluidic cell culture model

Heng-Hua Hsu, Ping-Liang Ko, Chien-Chung Peng, Ya-Jen Cheng, Hsiao-Mei Wu, and Yi-Chung Tung\*

Academic Sinica, Research Center for Applied Sciences  
Materials Today Bio 2023, DOI: 10.1016/j.mtbio.2023.100703

Sprouting angiogenesis is vital for vascular growth in various conditions. This study introduces a microfluidic device that supports 3D cell culture within a hydrogel matrix and generates stable oxygen gradients to study endothelial cell sprouting. Endothelial cells form a monolayer mimicking blood vessels, while adjacent hydrogels—with or without fibroblasts—serve as matrices for sprouting. Oxygen gradients are created using a spatially confined chemical reaction. Results show that oxygen gradients and fibroblast co-culture enhance endothelial sprouting by influencing cytokine levels and modifying the hydrogel's physical properties. This platform enables controlled simulation of in vivo-like microenvironments, allowing investigation of how biochemical and mechanical cues drive angiogenesis. The device serves as a versatile in vitro model for studying vascular development and disease mechanisms, with potential applications in drug screening and regenerative medicine.



# 魏培坤

## 研究員兼主任

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### 個人簡介

魏培坤教授現任中央研究院應用科學研究中心 (RCAS) 主任兼研究員，專長於奈米光子學在生物感測應用上的研究。目前，他的研究重點包括數位奈米電漿技術、低成本生物感測晶片及高通量篩選 (HTS) 成像技術。魏教授於 1994 年獲得國立台灣大學電機工程博士學位，專攻積體光學，隨後在中央研究院原子與分子科學研究所 (IAMS, AS) 從事近場光學領域的博士後研究。自 2000 年加入應用科學研究中心 (RCAS, AS) 以來，魏教授致力於研究奈米科學與工程技術。

魏教授在積體光學、近場光學、奈米光子學與生物感測相關領域發表超過 180 篇國際期刊論文，並取得 12 項專利，其中 3 項技術已成功技轉。他所開發的創新生物感測晶片與成像技術榮獲 2024 年國家新創獎，並正與台積電 (TSMC) 子公司合作開發。

魏教授的奈米光子感測技術與多家國內外研究機構合作開發，合作機構包括東京大學機械工程系 (光纖式感測技術)、北海道大學 (RIES, 奈米結構感測晶片)、國立台灣大學應用力學研究所 (PCR 產物檢測)、以及中央研究院物理研究所 (高通量篩選 (HTS) 技術應用於生物分子交互作用研究)。此外，作為導師，魏教授指導來自合作機構的研究生，培育奈米製程、光子元件與生物感測領域的新興人才。在學術服務方面，魏教授近年來擔任中央研究院關鍵議題中心 (RCCI, AS) 學術諮詢委員，並於 2024 年擔任 OPTIC Taiwan 會議主席，還是國科會矽光子計畫 (NSTC) 審查委員。

未來，魏教授的研究目標是將生物感測晶片與高通量篩選 (HTS) 成像技術推向實際應用，並聚焦於農藥殘留、環境荷爾蒙及感染性病毒的檢測，為公共衛生與環境監測提供先進解決方案。

### 代表著作

- 1 Ting-Wei Chang, Ting-Hao Chuang, Sheng-Hann Wang, Wing Kiu Yeung\*, Pei-Kuen Wei\*, "Self-referenced Digital Spectral Chromatic Local Surface Plasmon Resonance in Ultrasensitive Severe Sepsis Interleukin-6 Detection", ACS Sens. 2025, 10, 2, 1178–1186
- 2 (Patents) Pei-Kuen Wei, Ming-Yang Pan, Kuang-Li Lee: METHOD AND APPARATUS FOR SURFACE PLASMON RESONANCE IMAGING, US Patent No.: US 12,099,009 B2, Sep. 24, 2024; European Patent No. EP3861325 04.12.2024
- 3 Ting-Wei Chang, Sheng-Hann Wang, Iuan-Sheau Chin, Pei-Zhen Li, Shu-Cheng Lo, Shu-Yi Hsieh, Jung-Hsin Lin\*, Pei-Kuen Wei\*, "Biomimetic affinity sensor for the ultrasensitive detection of neonicotinoids", Biosens. & Bioelectron. 239, 2023, 115630
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- 5 Sheng-Hann Wang; Chia-Wen Kuo; Shu-Cheng Lo; Wing Kiu Yeung; Ting-Wei Chang; Pei-Kuen Wei\*, "Spectral Image Contrast-Based Flow Digital Nanoplasmon-metry for Ultrasensitive Antibody Detection", Journal of Nanobiotechnology. 2 20, (2022)

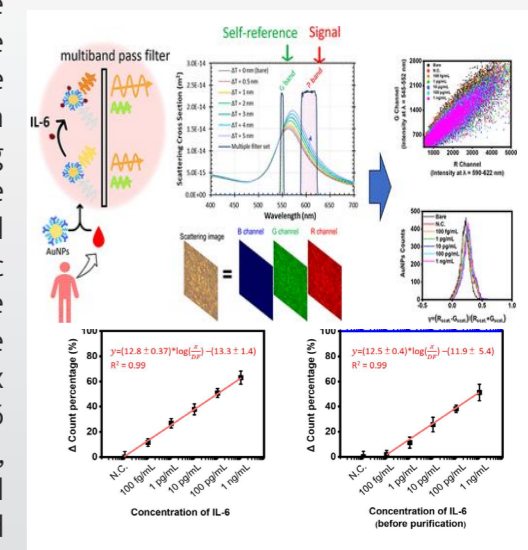
### 研究重點

#### Self-referenced Digital Spectral Chromatic Local Surface Plasmon Resonance in Ultrasensitive Severe Sepsis Interleukin-6 Detection

Ting-Wei Chang, Ting-Hao Chuang, Sheng-Hann Wang, Wing Kiu Yeung, Pei-Kuen Wei

Academic Sinica, Research Center for Applied Sciences  
ACS Sens. 2025, 10, 2, 1178–1186/j.bios.2023.115630

Interleukin-6 (IL-6) is a cytokine that mediates a range of physiological functions. It plays a crucial role in immune responses by regulating leukocyte activity and tissue inflammation and is also implicated in energy metabolism regulation. In this study, we employed a contrast imaging method to detect changes in the localized surface plasmon resonance of gold nanoparticles (AuNPs) induced by biomolecular binding. By digitally analyzing chromatic image contrast across numerous individual AuNPs, we significantly enhanced signal output, enabling sensitive detection even at low IL-6 concentrations in complex human blood plasma. The platform effectively detects IL-6 within 45 minutes, using only 0.5 mL of a 10-fold diluted, label-free sample. It achieved a limit of detection (LOD) and limit of quantification (LOQ) of less than 19.2 fg/mL and 87.8 fg/mL, respectively, with a recovery rate of 96%. This platform demonstrates strong potential as a rapid and efficient tool for clinical biomarker monitoring.

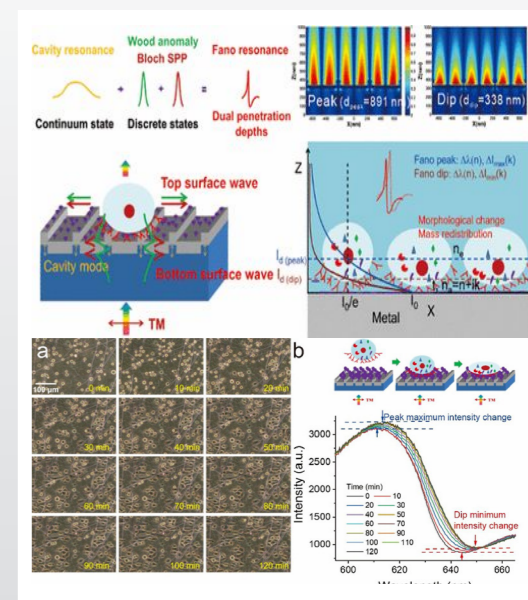


#### Aluminum-Coated Nanoridge Arrays with Dual Evanescent Wavelengths for Real-Time and Label-Free Cellular Analysis

Kuang-Li Lee, Hsien-San Hou, Xu Shi, Meng-Lin You, Ming-Yang Pan, Yasutaka Matsuo, Yasutaka Matsuo, Ji-Yen Cheng, Hiroaki Misawa, Pei-Kuen Wei

Academic Sinica, Research Center for Applied Sciences  
J. Phys. Chem. C 2024, 128, 8, 3384–3392/acs.jpcc.3c08016

We introduced the concept of Fano resonances with dual evanescent lengths in aluminum-coated nanoridge arrays for real-time, label-free analysis of cellular adhesion. This approach enables dual-range sensing and utilizes four-parameter plots to characterize both short-range and long-range adhesion behaviors. The shorter evanescent length of the Fano dip is sensitive to the cell–substrate adhesion interface, while the longer evanescent length penetrates deeper into the cellular medium, capturing broader cellular interactions such as cell–cell adhesion. When integrated with a hyperspectral imaging system, the aluminum-coated nanoridge arrays support multiplexed sensing of cell adhesion, offering a powerful tool for high-throughput cell biology research, immunotherapy, and drug discovery.



# 鄭 鄧 言

## 研究員

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## 個人簡介

在博士班期間，鄭鄧言博士建造了一套光學參量振盪器 (OPO) 雷射，以及一套自動化資料擷取系統，用來研究 DNA 嵌合 (chelating) 分子的振動光譜。在博士後研究期間，他整合了微流體技術與自動化系統，成功建構出一套可以同時合成 1,536 通道的寡核苷酸 (oligonucleotide) 合成儀。

在建立個人實驗室後，鄭博士及其團隊運用了雷射微加工技術，開發出各種微流體裝置，應用於生物研究。他們的實驗室已開發出可用於培養細胞 (包括哺乳類動物細胞株與幹細胞) 及生物體 (如斑馬魚與珊瑚叢片段) 的裝置。這些裝置使得研究人員能夠對培養中的細胞施加長期 (可達數週) 物理性刺激，例如電場、溫度變化與光刺激。

斑馬魚裝置能夠固定魚體並進行長期培養，並可進行細胞層級的觀察，協助合作的生物實驗室進行傷口癒合研究，探索斑馬魚的再生能力。珊瑚晶片則協助另一個生物實驗室挑選具有耐溫性的珊瑚品系，應用於珊瑚礁復育工作。

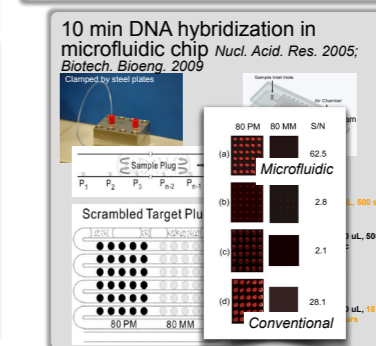
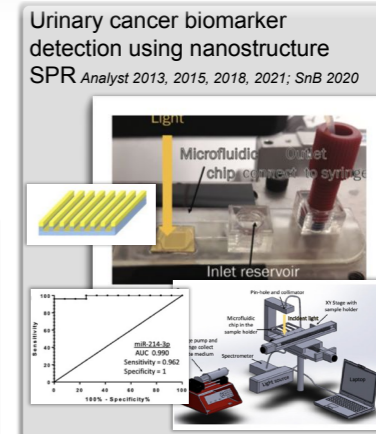
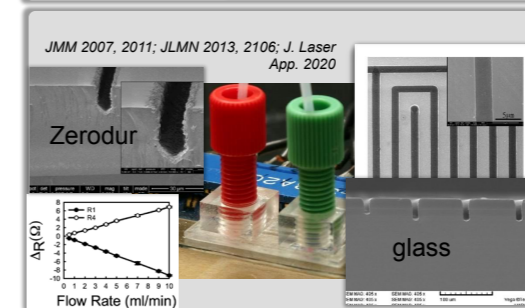
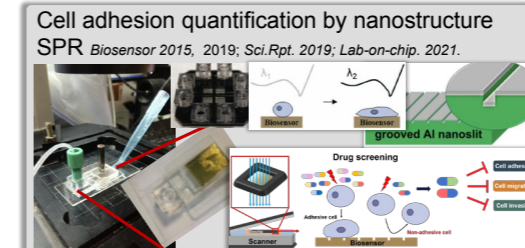
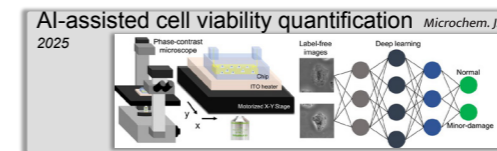
鄭博士的團隊成功取得大量細胞影像與光譜資料，用於人工智慧分析。近期，他們已成功應用 AI 進行無標記細胞存活率的定量分析。未來，他們將進一步整合 AI 程序控制與實驗室自動化技術，發展出適合單一實驗室的自動化細胞繼代培養系統。

## 代表著作

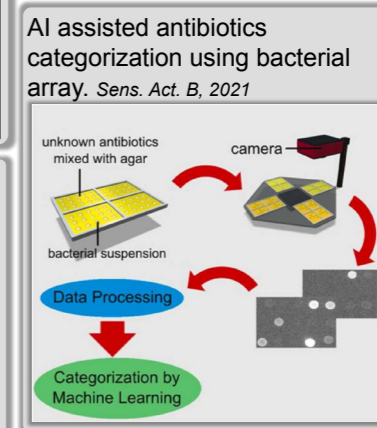
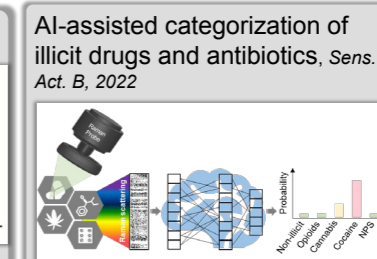
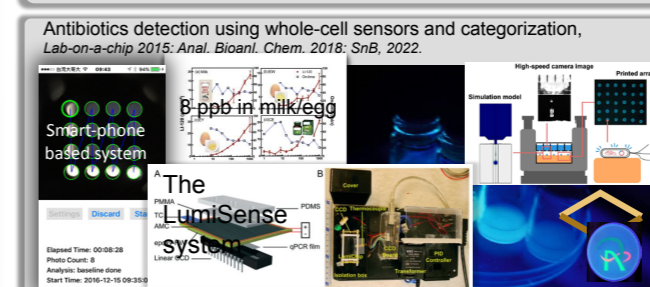
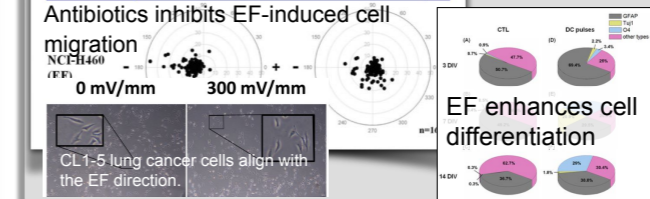
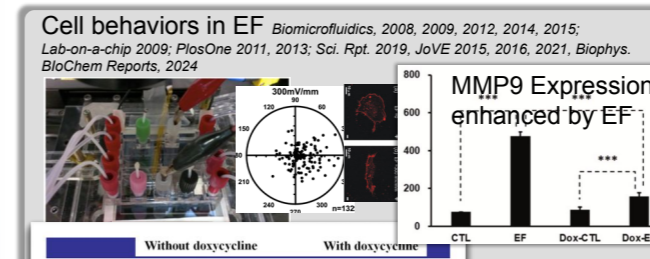
- 1 Chuang, P.S., Kao, W.C., Yu, Z.R., Lin, T.C., Shih, K.N., Yang, W.Y., Leung, Y.Y., Hsu, M.T., Chen, T.Y., Shikina, S. et al. (2025) Innovative chips for coral cultivation: Enhanced flexibility and experimental applications. *Methods Ecol Evol*, **16**, 707-714.
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## 研究重點

### Ji-Yen Cheng Research Highlight -1/2



### Ji-Yen Cheng Research Highlight -2/2





# 楊富量

## 特聘研究員

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### 個人簡介

楊富量 (Fu-Liang YANG) 博士，現任特聘研究員暨教授，專精於以光體積變化描記法 (Photoplethysmography, PPG) 進行非侵入式血糖 (Non-invasive Blood Glucose, NIBG) 量測技術。楊教授原本亦專注於心腦血管疾病物理性治療的研究，但因技術已完成專屬技轉，該領域研究已正式終止。他於英國劍橋大學取得博士學位。在 2013 年之前，曾任台積電 5 奈米 CMOS 前瞻計畫經理，以及國家奈米元件實驗室主任。

#### 主要研究成果與影響如下：

- 2024 年 國家新創獎 (技術非專屬授權進行中)  
創新耳機型含血壓等多功能生理感測器與居家智慧醫療應用
- 2022 年 國家新創獎 (技術非專屬授權)  
AI 演繹法非侵入式血糖機
- 2020 年 國家新創獎 (技術專屬授權並成功衍生新創公司)  
螺旋體外反搏系統 (HelixExternalCounterPulsationSystem)

楊教授及其團隊的最新一代非侵入式血糖量測技術已成功應用於空腹血糖的測量，但在飯後血糖的準確性表現仍有待提升。為克服飯後血糖偵測的挑戰，他們將進一步開發全新的人工智慧演算法，並與台北慈濟醫院合作，針對加護病房病患進行資料收集。首要的合作目標，是能夠即時偵測低血糖，或進行早期預測以提供預警。

### 代表著作

- 1 Bitewulign Kassa Mekonnen, Wei-Ru Lu, Tung-Han Hsieh, Justin Chu, & Fu-Liang Yang\*. **Accurate and 30-plus days reliable cuffless blood pressure measurements with 9-minutes personal photoplethysmograph data and mixed deduction learning.** Scientific Reports volume 14, Article number: 23722(2024). <https://doi.org/10.1038/s41598-024-75583-y>
- 2 Wei-Ru Lu, Wen-Tse Yang, Justin Chu, Tung-Han Hsieh & Fu-Liang Yang\*. **“Deduction learning for precise noninvasive measurements of blood glucose with a dozen rounds of data for model training”** Scientific Reports volume 12, Article number: 6506(2022), <https://doi.org/10.1038/s41598-022-10360-3>
- 3 Chu, J.; Yang, W.-T.; Lu, W.-R.; Chang, Y.-T.; Hsieh, T.-H.; Yang, F.-L\*. **“90% Accuracy for Photoplethysmography-Based Non-Invasive Blood Glucose Prediction by Deep Learning with Cohort Arrangement and Quarterly Measured HbA1c.”** Sensors 2021, 21, 7815. <https://doi.org/10.3390/s21237815>
- 4 Justin Chu, Wen-Tse Yang, Yao-Ting Chang\* and Fu-Liang Yang\* **“Visual Reassessment with Flux Interval Plot Configuration after Automatic Classification for Accurate Atrial Fibrillation Detection by Photoplethysmography”** Diagnostics 2022, 12, 1304. <https://doi.org/10.3390/diagnostics12061304>
- 5 Justin Chu, Wen-Tse Yang, Tung-Han Hsieh, Fu-Liang Yang\*, Feb. 2021 **“One-Minute Finger Pulsation Measurement for Diabetes Rapid Screening with 1.3% to 13% False-Negative Prediction Rate”** Biomedical Statistics and Informatics 2021; 6(1):6-13, DOI:10.11648/j.bsi.20210601.12

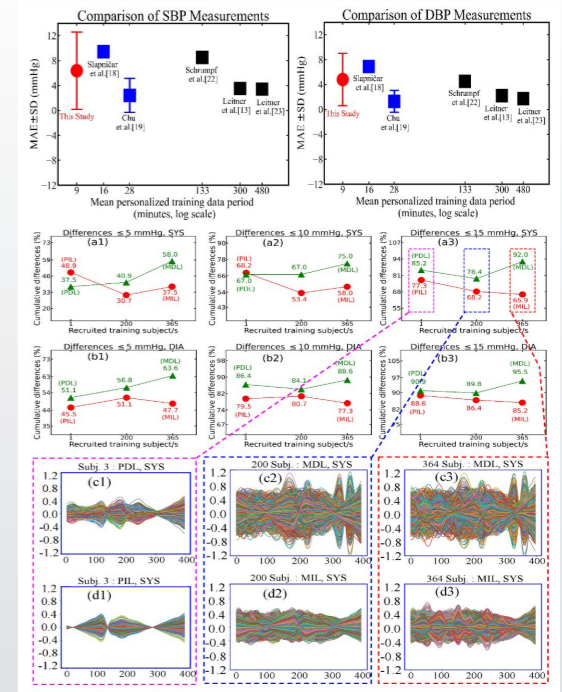
### 研究重點

## Accurate and 30-plus days reliable cuffless blood pressure measurements with 9-minutes personal photoplethysmograph data and mixed deduction learning

Bitewulign Kassa Mekonnen, Wei-Ru Lu, Tung-Han Hsieh, Justin Chu and Fu-Liang Yang

Scientific Reports volume 14, Article number: 23722 (2024)

To further meet the clinical accuracy requirements, PPG-only BP predictions with personalized modeling for overcoming personal deviations have been widely studied, but all required tens to hundreds of minutes of personal PPG measurements for training. Since our objective is commercial application and a substantial reduction in training data, we tailored our model training to closely mimic real-world usage. To achieve this, we developed a training approach that only requires 9-minutes of personal PPG signal recordings and mixed with other PPG data from our recruited 364 subjects. The modeling is conducted with two-channel paired inputs to the convolutional neural network (CNN)-based model, which we called Mixed Deduction Learning (MDL). The test results of 88 samples from 15 subjects, under testing period up to 30-plus days without extra calibration, revealed that MDL meets most of the standards of AAMI, BHS, and IEEE 1708–2014 (for static test only) for BP measurement devices, which indicates MDL's long-term stability and consistency. Furthermore, we found that the model with two-channel inputs presents a trend of improving performance as the pool of mixed training data increased, while the conventional one-channel input revealed degraded performance. The outperformance of MDL is attributed to many significant features remained in the first CNN layer even when mixing personal 9-minutes data with the other 364 subjects. Consequently, PPG-only with MDL introduces a new avenue for overcoming challenges in training due to personal physiological variations. Given our consideration of real-life usage, this technology can be seamlessly translated to commercial applications.

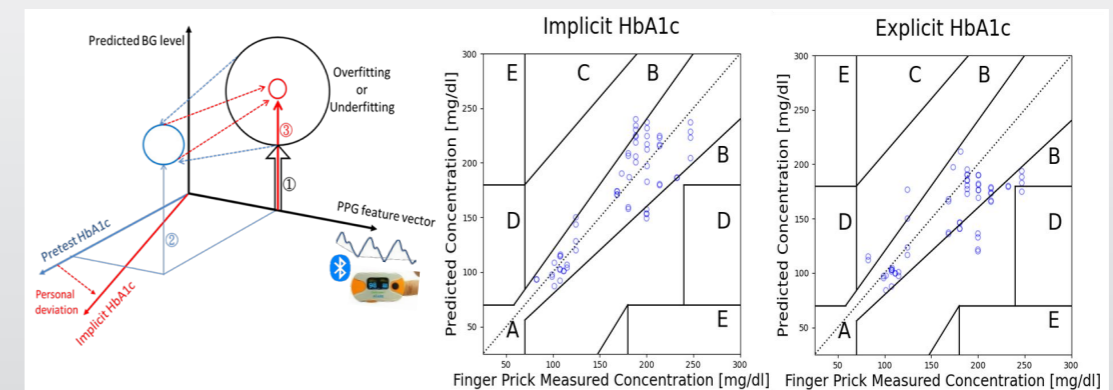


## Implicit HbA1c Achieving 87% accuracy for Non-invasive Fasting Blood Glucose Measurements within 90 days by Photoplethysmography

Justin Chu, Yao-Ting Chang, Shien-Kuei Liaw and Fu-Liang Yang \*

Bioengineering 2023, 10(10), 1207

To reduce the error induced by overfitting or underfitting in predicting non-invasive fasting blood glucose (NIBG) levels using photoplethysmography (PPG) data alone, we previously demonstrated incorporating HbA1c feature led to a notable 10 % improvement in NIBG prediction accuracy (the ratio in zone A of Clark's error grid). However, this enhancement came at the cost of requiring an additional HbA1c measurement, thus unfriendly to users. In this study, the enhanced HbA1c NIBG model (blood glucose level predicted from PPG and HbA1c) is trained with 1494 measurements, and we replaced the HbA1c measurement (explicit HbA1c) with “implicit HbA1c” which is reversely derived from pretested PPG and finger pricked blood glucose level.





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## 個人簡介

陳培菱教授目前擔任應用科學中心研究員，專精於生醫材料與生物影像技術開發。他的研究興趣聚焦於奈米醫學領域，尤其致力探討奈米粒子與腫瘤之間的交互作用。他們的研究團隊致力開發多種奈米粒子與影像工具，以深入了解奈米粒子到達及累積在腫瘤的機制。陳教授畢業於美國加州大學爾灣分校並獲得化學博士，過去數年，陳教授已應邀在國際會議發表超過七十場演講，包括全體大會與主題演講，並主辦超過二十場國際研討會。

陳培菱教授的研究團隊開發的即時雙光子活體影像技術，在相關領域受到高度肯定。他們協助多位醫師透過動物疾病模型深入理解疾病機制，並透過量化藥物載體在不同疾病模型中的分佈情形，協助優化藥物遞送效率，展現學術研究成果直接促進醫療實務應用的效益。

近年來，陳培菱教授已主導超過四項跨領域合作研究計畫。身為計畫總主持人，陳教授成功促進不同領域專家的深度交流與合作。此外，為推廣奈米醫學研究發展，陳教授共同創立台灣奈米醫學學會，並擔任常務監事；同時擔任台灣奈米科技產業發展協會副理事長，以及位於新加坡之亞洲奈米論壇執行委員，積極推動奈米技術的產業化及國際合作。身為導師，陳教授已指導十位研究生，培育未來奈米科技人才。

## 代表著作

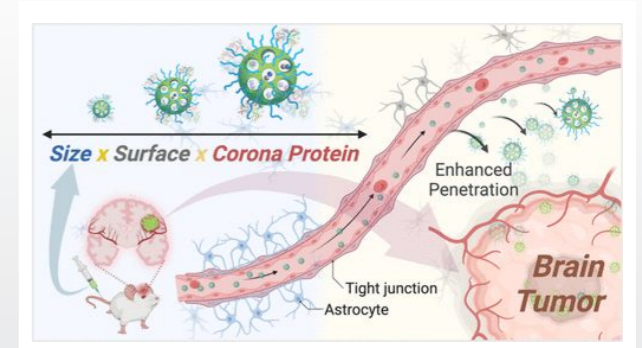
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## 研究重點

### Receptor Ligand-Free Mesoporous Silica Nanoparticles

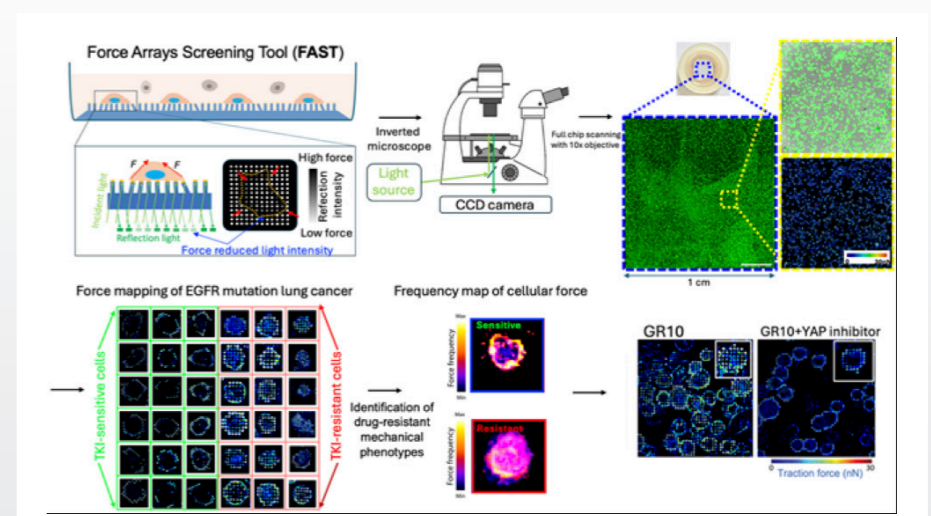
ACS Nano 2024, 18, 12716–12736

Mesoporous silica nanoparticles (MSNs) represent a promising avenue for targeted brain tumor therapy. However, the blood–brain barrier (BBB) often presents a formidable obstacle to efficient drug delivery. This study introduces a ligand-free PEGylated MSN variant (RMSN25-PEG-TA) with a 25 nm size and a slight positive charge, which exhibits superior BBB penetration. Utilizing two-photon imaging, RMSN25-PEG-TA particles remained in circulation for over 24 h, indicating significant traversal beyond the cerebrovascular realm. Importantly, DOX@RMSN25-PEG-TA, our MSN loaded with doxorubicin (DOX), harnessed the enhanced permeability and retention (EPR) effect to achieve a 6-fold increase in brain accumulation compared to free DOX. In vivo evaluations confirmed the potent inhibition of orthotopic glioma growth by DOX@RMSN25-PEG-TA, extending survival rates in spontaneous brain tumor models by over 28% and offering an improved biosafety profile. Advanced LC-MS/MS investigations unveiled a distinctive protein corona surrounding RMSN25-PEG-TA, suggesting proteins such as apolipoprotein E and albumin could play pivotal roles in enabling its BBB penetration.



### Spatial Force Distribution as a Biomarker for Cancer Cell Identification and Drug Resistance Detection

Force Arrays Screening Tool (FAST) provides a novel, high-throughput, label-free, user-friendly, and real-time approach to measure cellular traction forces at single-cell resolution. By rapidly screening cells based on mechanical properties, FAST enables detailed phenotypic characterization and efficient drug sensitivity testing. Its capability to simultaneously map traction forces across thousands of cells delivers unprecedented insights into dynamic cellular behaviors under physiological conditions. We demonstrate that spatial traction force distributions are potent biophysical biomarkers for distinguishing cellular phenotypes. Specifically, FAST identified distinct traction patterns that differentiate drug-sensitive from drug-resistant lung cancer cells. Importantly, these mechanical signatures correlate with key molecular regulators, YAP and  $\beta$ 1-integrin. Pharmacological inhibition of YAP and  $\beta$ 1-integrin successfully reverted drug-resistant mechanical phenotypes, restoring responsiveness to tyrosine kinase inhibitors (TKIs). FAST thus significantly advances cellular mechanobiology research and clinical applications, offering powerful opportunities for improved drug discovery, cancer diagnostics, and identification of therapeutic targets based on mechanical phenotype profiling.



# 林榮信

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## 個人簡介

林榮信教授為應用科學中心研究員。林教授於 1996 年至 2000 年於德國于利希研究院攻讀博士學位，研究領域為細胞膜蛋白的分子動力學模擬，是該領域的先驅之一。2000 年 1 月獲得博士學位後，於于利希研究院的馮諾曼計算研究所擔任科學研究員，同年 9 月轉入美國加州大學聖地亞哥分校，在霍華休斯醫學研究所擔任生物資訊學專家，期間將研究領域拓展至計算藥物設計，是首批將蛋白質動力學應用於基於結構的藥物設計的學者之一。2003 年初，在國立臺灣大學醫學院藥學院擔任助理教授，開始其獨立研究生涯。2006 年中受延攬至中央研究院應用科學研究中心，現亦為國立臺灣大學醫學院藥學院合聘教授。

林教授的研究重點是開發用於計算藥物探索和結構生物資訊學的新穎方法，並將其應用於探索天然物分子和其他藥物的新穎候選藥物和生物分子標靶。舉一近期研究成果為例，林教授實驗室開發了基於統計力學第一原理的結合自由能計算方法，可應用於各類生物分子的交互作用，包括蛋白質、肽和小分子化學分子。此外，林博士實驗室致力於提升分子嵌合 (molecular docking) 方法預測的準確性及拓展其可應用領域。一些新穎的應用包括 MEDock、SLITHER 和 idTarget，其中 idTarget 則是首次實現了在蛋白質體範圍基於分子嵌合計算的把點，可用於預測合成的化學小分子或天然物分子的作用靶點。林教授實驗室已開發深度學習演算法和其他人工智慧方法來應用於開發藥物設計的新穎計算方法。他過去與幾個團隊合作研發的新藥已獲得 16 項專利。兩系列針對神經退化性疾疾病和癌症治療的候選藥物分別於 2015 年和 2016 年在國內獲得專屬授權。其中用於治療阿茲海默症的口服小分子藥物已於 2025 年 2 月開始 I 期首次人體臨床試驗。

林教授自 2003 年回國以來，參與多個合作團隊，致力於結構生物資訊方的開發，以及多種疾病的藥物研發。2015 年至 2020 年擔任中央研究院應用科學研究中心生醫應用專題中心執行長，2019 年至 2020 年擔任中央研究院生醫轉譯研究中心副主任。2020 年 11 月起，擔任生醫轉譯研究中心 (BioTReC) 副主任，2021 年至 2024 年也曾擔任 BioTReC 智慧醫學專題中心執行長。

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- 2 Dhananjay C. Joshi, Charlie Gosse, Shu-Yu Huang and **Jung-Hsin Lin\***, **A curvilinear-path umbrella sampling approach to characterizing the interactions between rapamycin and three FKBP12 variants *Front. Mol. Biosci.* 9: 879000 (2022)**
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- 4 Jui-Chih Wang, Pei-Ying Chu, Chung-Ming Chen and **Jung-Hsin Lin\*** **idTarget: a web server for identifying proteins targets of small chemical molecules with robust scoring functions and a divide-and-conquer docking approach. *Nucleic Acids Res.* 40: W393-W399 (2012).**
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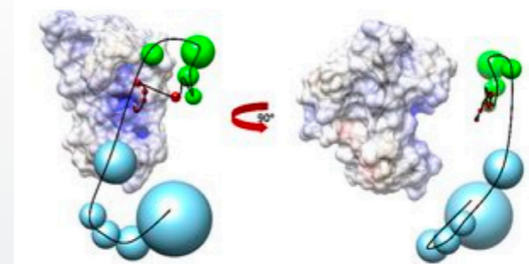
## 研究重點

### Delineating Protein-Protein Curvilinear Dissociation Pathways and Energetics with Naïve Multiple-Walker Umbrella Sampling Simulations

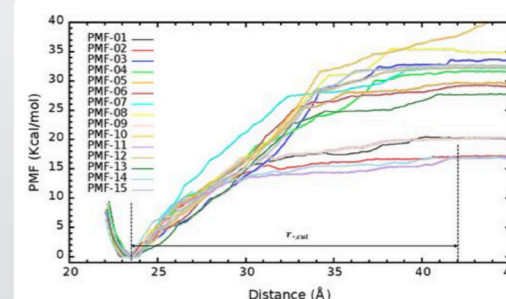
Dhananjay C. Joshi, **Jung-Hsin Lin\***

Academic Sinica, Research Center for Applied Sciences  
*J. Comput. Chem.*, 2019, DOI: DOI:10.1002/jcc.25821

The protein-protein interaction energetics can be obtained by calculating the potential of mean force (PMF) from umbrella sampling (US) simulations, in which samplings are often enhanced along a predefined vector as the reaction coordinate. However, any slight change in the vector may significantly vary the calculated PMF, and therefore the energetics using a random choice of vector may mislead. A non-predefined curve path-based sampling enhancement approach is a natural alternative, but was relatively less explored. In this work, dissociation of the barnase-barstar complex is simulated by implementing non-predefined curvilinear pathways in US simulations. A simple variational principle is applied to determine the lower bound PMF, which could be used to derive the standard free energy of binding. Two major dissociation pathways, which include interactions with the RNA-binding loop and the Val 36 to Gly 40 loop, are observed. Further, the proposed approach was used to discriminate the decoys from protein-protein docking studies.



Traces of curvilinear physical transitions for barnase-barstar from sequential US MD simulations.



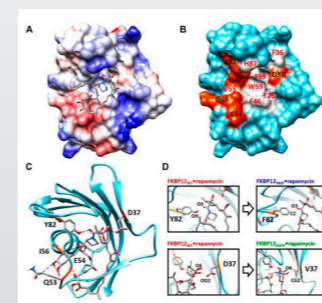
A variational principle-based approach was adopted to selected the PMF.

### A Curvilinear-Path Umbrella Sampling Approach to Characterizing the Interactions Between Rapamycin and Three FKBP12 Variants

Dhananjay C. Joshi, Charlie Gosse, Shu-Yu Huang and **Jung-Hsin Lin\***

Academic Sinica, Research Center for Applied Sciences  
*Front. Mol. Biosci.* 9: 879000 (2022) DOI: 10.3389/fmol.2022.879000

Rapamycin is an immunosuppressant macrolide that exhibits anti-proliferative properties through inhibiting the mTOR kinase. Despite the availability of structural and thermodynamic information on the interaction of FKBP12 with rapamycin, the energetic and mechanistic understanding of this process is still incomplete. In the present paper, we extend our investigations to a protein-small molecule duo, the FKBP12-rapamycin complex. We estimate the binding free energies of rapamycin with wild-type FKBP12 and two mutants in which a hydrogen bond has been removed, D37V and Y82F. On one hand, removing the carboxylate group of D37 strongly destabilizes the association; on the other hand, the hydroxyl group of Y82 is nearly unnecessary for the stability of the complex because some nonconventional, cryptic, indirect interaction mechanisms seem to be at work.



Structure of the FKBP12-rapamycin complex as determined in PDB 1FKB.

- (A) Coulombic surface representation
- (B) Surface representation of the protein alone with the hydrogen-bond forming residues in orange and the hydrophobic residues in gray.
- (C) The five hydrogen bonds formed between FKBP12 and rapamycin are shown as dashed lines.
- (D) Close-up view on the Y82 and D37 residues and resulting starting conformation obtained after either the Y82F or the D37V substitution.

# 李超煌

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## 個人簡介

李超煌博士於 1997 年自台灣大學電機工程學研究所獲得博士學位後，在中央研究院原子與分子科學研究所進行 2 年博士後研究，並於 2000 年加入中央研究院應用科學研究中心擔任助研究員，2010 年升等為研究員。他的研究領域包括光學顯微技術、細胞與微環境的交互作用，以及微流道元件在生物醫學上的應用等。

在光學顯微技術方面，李博士是「差動共焦顯微術」和「非干涉式廣視野光學測繪術」等光學奈米級量測技術的主要發明人。自 2008 年起，他開始利用微流道元件來控制細胞微環境，並與臨床醫師合作，研究癌細胞在微環境參數改變下的運動行為變化，並證實癌細胞與纖維母細胞之間的旁分泌迴圈。最近，李博士的團隊開發了 3D 細胞培養平台，進行合併不同藥物的治療法對癌細胞抗藥性影響的測試，並同時進行神經細胞在 3D 培養環境中的分化和再生研究。

自 2004 年起，李超煌博士便合聘於陽明交通大學生醫光電研究所，並於 2011 年至 2014 年擔任該所所長，持續授課並指導研究生。除此之外，李博士長期與生物學及醫學領域的專家合作，積累了豐富的跨領域研究經驗。自 2016 年起，他擔任中央研究院學術諮詢總會的副執行秘書，負責數理科學組的研究計畫、經費管理、研究人員聘任與升等審查等學術行政事務。自 2024 年起，李博士擔任新成立的關鍵議題研究中心的首位主任。

李博士將繼續探討癌細胞在 3D 環境中的運動行為，以及它們對多種藥物與療法的反應。他還將關注神經細胞在外部刺激下的再生潛力。除了研究，他也致力於發展關鍵議題研究中心的硬體設施和人力資源，並推動符合中央研究院政策目標的任務導向型計畫。

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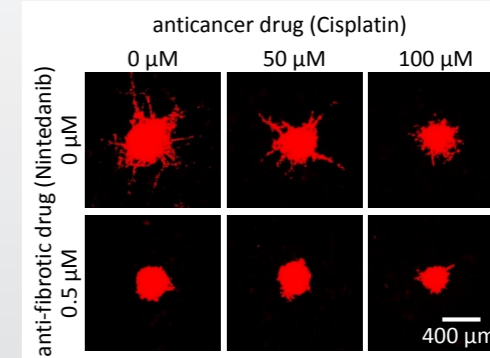
## 研究重點

### A 3D culture system for evaluating the combined effects of cisplatin and anti-fibrotic drugs on the growth and invasion of lung cancer cells co-cultured with fibroblasts

H.-J. Pan, C.-W. Lee, L.-Y. Wu, H.-H. Hsu, Y.-C. Tung, W.-Y. Liao, and C.-H. Lee

Research Center for Applied Sciences, Academia Sinica  
*APL Bioengineering* **7**, 016117 (2023)

We developed a 3D co-culture system composed of the mixture of fibrin and Matrigel to mimic the tumor microenvironment for studying the impact of drug combinations on a tumor of lung cancer cells co-cultured with fibroblasts. The results demonstrated that an anti-fibrotic drug, nintedanib, could improve the effect of an anticancer drug, cisplatin, to reduce tumor growth and invasion. We also identified four genes in fibroblasts relevant to cell adhesion, invasion, or ECM degradation that were reduced by nintedanib in this co-culture system. This work was also reported by *Genetic Engineering & Biotechnology News*, March 29, 2023.

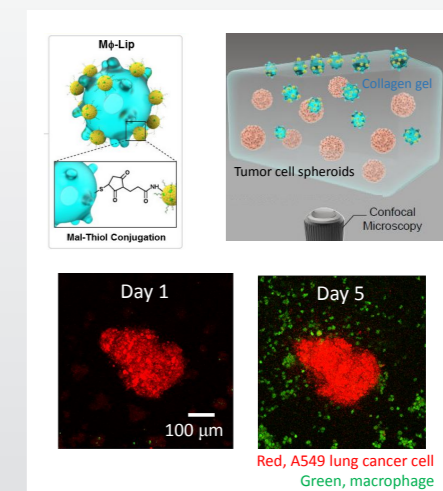


### A 3D cell culture platform for evaluating macrophage-liposome conjugates in combination chemotherapy

C.-C. Kuo, W.-Y. Liao, Y.-J. Lin, and C.-H. Lee

Research Center for Applied Sciences, Academia Sinica  
*J. Biomed. Mater. Res. A* **113**, e37939 (2025).

We collaborated with Dr. Yu-Jung Lin to assess the capability of macrophages delivering chemotherapy directly to tumor cells. We created a 3D cell culture system that closely mimicked real tumors, allowing us to watch how macrophages carrying drug-filled liposomes (called M $\phi$ -Lip) moved, invaded, and killed tumor cells. We tested the drug combination of cisplatin (CDDP) and paclitaxel (Taxol) at various concentrations, and found that the types and amounts of drugs affected how well the macrophages infiltrated into the collagen gel surrounding a tumor cell spheroid. The results suggest that Taxol could increase the diameters of liposomes and thus reduced the infiltration efficiency of the drug-carrying macrophages. This platform could help fine-tune targeted drug delivery and improve cancer treatment outcomes in the future.





# 薛景中

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## 個人簡介

薛景中博士是專門從事表面和介面分析與科學的研究員。他的研究興趣包括利用團簇離子束與表面電子能譜和表面(串聯)質譜,分析生物和有機-無機複合材料。此外,他還使用能偵測能量耗散的石英晶體微量天平,研究固液界面處活細胞和分子與表面的交互作用。薛博士致力於推動該領域的知識和創新。他於Case Western Reserve University 材料科學與工程系獲得博士學位,並為多個國際研究計畫做出了貢獻。

薛博士提出了原子和團簇離子共濺射技術,現在應用於X光光電子能譜和二次離子質譜,影響有機發光二極體、有機鹵化物鈦鈳礦、體異質結複合材料等材料的界面分析。

薛博士曾與北京大學、南京郵電大學、西北工業大學、天光材料科技公司、台灣大學、清華大學、陽明交通大學、成功大學等合作,分析及了解有機發光二極體、太陽能電池、憶阻器等薄膜元件內部結構的變化。他還擔任《膠體與界面科學雜誌》的聯合編輯,並擔任在International Conference for Colloids and Interfaces (西班牙)、化學年會(台灣)、國家科學技術委員會化學學門、分析化學與物理化學交流研討會、East Asia Microscopy Conference、Scientific International Symposium on SIMS and Related Techniques Based on Ion-Solid Interactions 等的委員會成員、組織者或分組會議主席。他也是台灣顯微鏡學會的理監事。

薛博士未來的研究旨在加深對團簇離子濺射的理解和應用,並加強跨領域合作。他致力於將學術發現轉化為現實世界的應用,確保對學術界和社會產生持久影響。

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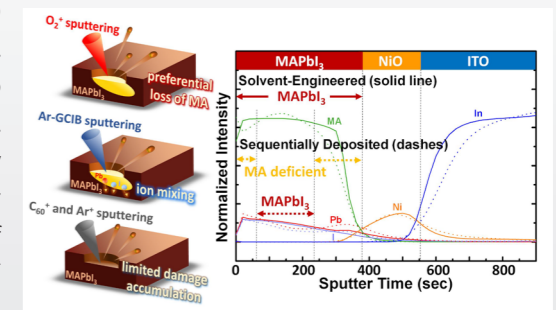
## 研究重點

### Validated Analysis of Component Distribution Inside Perovskite Solar Cells and Its Utility in Unveiling Factors of Device Performance and Degradation

Cheng-Hung Hou, Shu-Han Hung, Li-Ji Jhang, Keh-Jiunh Chou, Yu-Kai Hu, Pi-Tai Chou, Wei-Fang Su, Feng-Yu Tsai, Jay Shieh, and Jing-Jong Shyue\*

Academic Sinica, Research Center for Applied Sciences  
ACS Applied Materials & Interfaces **12** [20] 22730-22740 (2020) DOI:10.1021/acsami.9b22492

Time-of-flight secondary-ion mass spectrometry (ToF-SIMS) has been used for gaining insights into perovskite solar cells (PSCs). However, the importance of selecting ion beam parameters to eliminate artifacts in the resulting depth profile is often overlooked. In this work, significant artifacts were identified with commonly applied sputter sources, i.e., an  $O_2^+$  beam and an Ar-gas cluster ion beam (Ar-GCIB), which could lead to the misinterpretation of the PSC structure. On the other hand, polyatomic  $C_{60}^+$  and  $Ar^+$  ion beams were found to be able to produce depth profiles that properly reflect the distribution of the components. Based on this validated method, differences in component distribution, depending on the fabrication processes, were identified and discussed. The solvent engineering process yielded a homogeneous film with higher device performance, but sequential deposition led to a perovskite layer sandwiched by methylammonium-deficient layers that impeded the performance. For device degradation, it was found that most components remained intact at their original position except for iodide. This result unambiguously indicated that iodide diffusion was one of the key factors governing the device lifetime. With the validated parameters provided, ToF-SIMS was demonstrated as a powerful tool to unveil the structure variation amid device performance and during degradation, which are crucial for the future development of PSCs.



### Adsorption of Drug Guest Molecules in Metal-Organic Frameworks Studied by Quartz Crystal Microbalance with Dissipation (QCM-D)

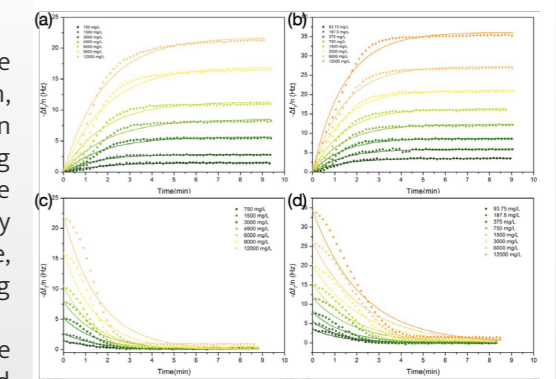
Wen-Yi Yu and Jing-Jong Shyue\*

Academic Sinica, Research Center for Applied Sciences

Guest molecules absorption and desorption processes in the aqueous phase were examined by QCM-D, and Acetaminophen, Caffeine and Aspirin were chosen for this study. The preparation of UiO-66-coated quartz crystal chip was via the spin-coating method. It was found that the absorption process was repeatable and reproducible. Furthermore, the degree of absorption varied by the guest molecule, and in descending order were aspirin, caffeine, acetaminophen due to electric charge, polarity and  $\pi$ - $\pi$  stacking interaction.

In order to study the effect of environment on guest uptake in MOF, the absorption and desorption processes were observed under different pHs. As pH value went down, the absorption of acetaminophen decreased due to the failure to form hydrogen bond with UiO-66 which was surrounded by more protons at lower pH. However, the caffeine absorption slightly increased, owing to the enhance of the electrostatic interaction caused by the increase of UiO-66 zeta potential at lower pH. For aspirin, the absorption first raised and then descended at pH 3. The increase resulted from the zeta potential of uiO-66 as well, while the decrease was caused by dissociated aspirin molecules getting back protons at lower pH. It led to molecular become neutral, and reduce the electrostatic interaction.

The drug absorption and desorption kinetics was also investigated, and the result showed that non-linear pseudo first order kinetic model was the most suitable one. There was good correlation between models and experiment data. Moreover, the interaction between MOF and guest would have an effect on absorption and desorption kinetics.





# 郭志禹

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### 個人簡介

郭志禹博士專長於流體力學、土石流與環境力學。他的研究興趣包括土石流、崩塌地監測與邊坡穩定分析，致力於推進這些領域的知識與創新。郭博士於英國劍橋大學工程學系取得博士學位。

郭博士開發了崩塌地體積估算方法、多時序差分干涉合成孔徑雷達 (MtinSAR) 影像資料分析方法以及崩塌地活動性評估指標。這些方法目前已應用於行政院農業部農村發展及水土保持署深層山崩的長期監測與防災規劃中。

郭博士曾與國立台北科技大學、國立中央大學、國立成功大學等研究單位進行合作，研究領域包括山崩塌、MtinSAR 資料分析及地下水流等。他也指導學生進行地球科學、山崩運動與流體力學等方面的研究。此外，他擔任多本期刊的審稿人，包括《Engineering Geology》、《Remote Sensing》、《Granular Matters》、《Physics of Fluids》、《Energy》和《Journal of Sound and Vibrations》等。

郭博士的未來研究目標是深化山崩與防災等研究，並加強跨領域合作。他致力於將學術發展的技術轉化為實際應用，為學術界與社會做出貢獻。

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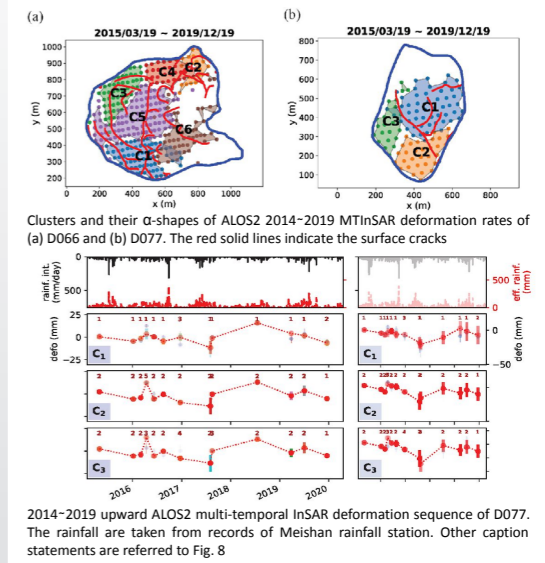
### 研究重點

#### Application of statistical clustering to diagnose sub-zone activities in potential deep-seated landslide sites

Pi-Wen Tsai, Chih-Yu Kuo<sup>1</sup>, Rou-Fei Chen

<sup>1</sup>Academic Sinica, Research Center for Applied Sciences

Multi-Temporal Interferometric Synthetic Radar (MTInSAR) is a remote sensing technology, which can provide high accuracy and wide coverage of transient surface deformation through analyzing a sequence of radar interferograms. It has been applied to hazard mitigation planning for potential deep-seated landslides and long-term monitoring of the slope activities in Taiwan. In this study, a Gaussian mixture model is proposed to perform statistical clustering for the surface deformation data points, associated clusters are defined to connect multitemporal deformation clusters, and the time series of the deformation clusters can be composed. These techniques enable investigations on the relations among the time series of the deformation clusters, precipitations or other influential factors of the landslide activities. The results indicate that the method can be further deployed for wider deep-seated landslide applications.

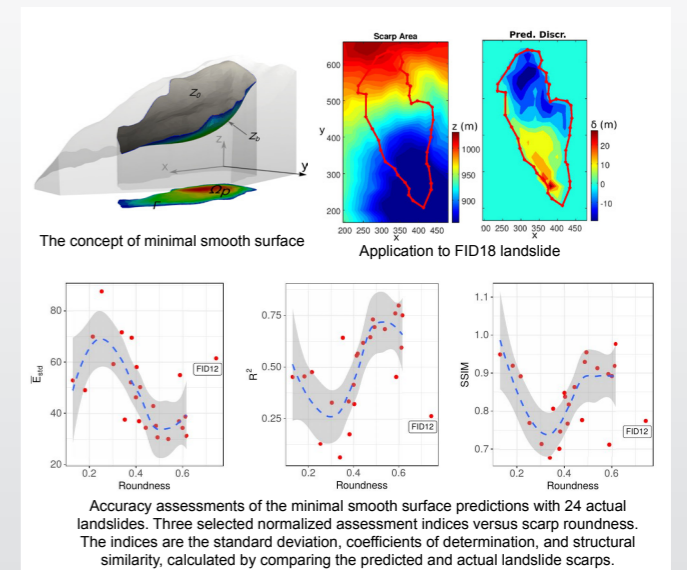


#### Application assessments of using scarp boundary-fitted, volume constrained, smooth minimal surfaces as failure interfaces of deep-seated landslides

Chih-Yu Kuo<sup>1</sup>, P.W. Tsai, Y. C. Tai, Y. H. Chan, R. F. Chen, C. W. Lin

<sup>1</sup>Academic Sinica, Research Center for Applied Sciences  
*Front. In Earth Sci.*, 2020, DOI: 10.3389/feart.2020.00211

More than 9,000 potential deep-seated landslide sites in the mountain ranges of Taiwan have been identified by a series of governmental hazard mitigation initiatives after the 2009 Morakot typhoon. Among them, 186 sites have protection targets where thorough mitigation strategies are to be implemented. One of the important tasks is to estimate the volume, failure interface and related quantities of each landslide site. With this number of sites, an automated tool is needed to generate predictions at low operational costs. We propose to use volume-constrained smooth minimal surfaces to approximate the landslide failure interfaces. A volume-constrained smooth minimal surface in the current context is defined as a differentiable surface that encloses a given landslide volume with the minimal surface area. Although the stratigraphy and geological structures are omitted, the smooth minimal surface method is verified with 24 known landslides and is shown to be able to generate acceptable, approximated failure interfaces. A collection of assessment indices is employed to measure the fitness of the predictions





# 陳壁彰

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## 個人簡介

陳壁彰，2001年自台大化學系學士畢業，2003年台大化學所畢業，研究中孔洞材料的型態變化。於2011年，美國德州大學奧斯汀分校化學暨生化系博士畢業，從事非線性拉曼光學顯微鏡技術，在化學影像上的生物應用。2011至2014於美國霍華休斯醫學院 (Howard Hughes Medical Institute) 和2014年諾貝爾化學獎得主 Eric Betzig 從事博士後研究，開發「晶格層光顯微鏡」，針對快速三維活體螢光掃描，此工作獲得 AAAS Newcomb Cleveland Prize。於2014年加入中央研究院應用科學中心，擔任助研究員，2025年升為研究員迄今，主要進行開發三維大組織之高解析層光顯微鏡，利用單分子影像技術『透化層光定位顯微鏡』可以成功的看到記憶蛋白質分子在全果蠅腦組織中的空間分佈。及樣品膨脹技術『聚丙烯酸鉀膨脹層光奈米顯微術』，結合了樣品放大術及層光顯微鏡，讓光學顯微鏡在三維的大組織影像，可以有趨近電子顯微鏡的空間解析且擁有多色的螢光染色標記。未來期望可以將光學顯微術的解析度達到電子顯微鏡之解析度。此相關研究成果曾獲第十八屆有庠科技論文獎，中央研究院年輕學者研究成果獎，亦獲得中研院前瞻計畫，及科技部優秀年輕學者研究計畫補助。

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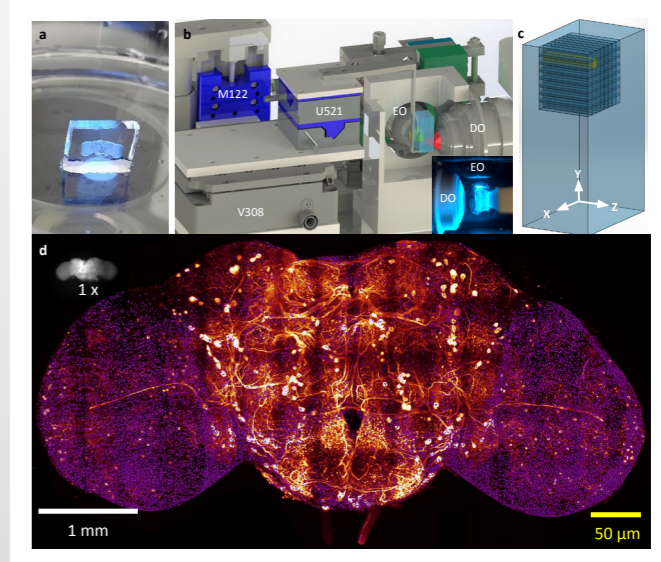
## 研究重點

### Rapid lightsheet fluorescence imaging of whole Drosophila brains at nanoscale resolution by potassium acrylate-based expansion microscopy

Tian, X.; Lin, T.-Y., L.; Lin, P.-T., Tsai, M.-J., Chen, H.; Chen, W.-J.; Lee, C.-M.; Tu, C.-H.; Hsu, J.-C.; Hsieh, T.-H.; Tung, Y.-C.; Wang, C.-K.; Lin, S.; Chu, L.-A.; Tseng, F.-G.; Hsueh, Y.-P., Lee, C.-H.; Chen, P.; Chen, B.-C.\*

Academic Sinica, Research Center for Applied Sciences  
*Nature Communications*, 15, 10911  
DOI:10.1038/s41467-024-55305-8 (2024)

To extend the resolution of optical microscopy towards that achievable by electron microscopy, whilst allowing colorful visualization of tissues in 3D, we have developed a potassium (poly) acrylate-based expansion microscopy (ExM) platform with an axicon-based Bessel lightsheet microscope equipped with long-working distance objectives and long travelling distance voice-coil stages. The good mechanical strength of our hydrogels could be mounted and translated in 3D for sample scanning via lightsheet imaging, resulting in a 40x plus increased resolution

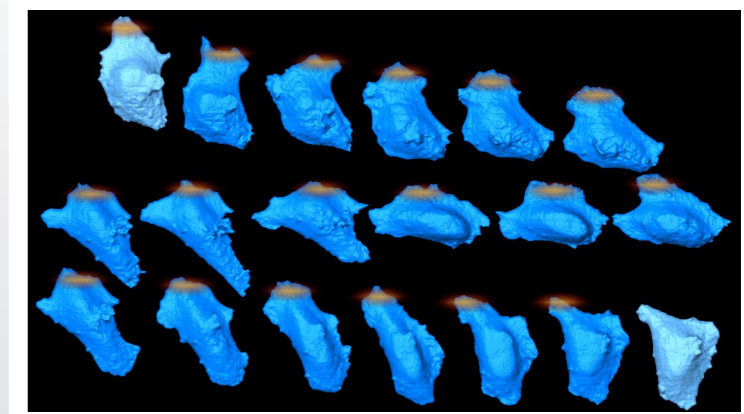


### Optogenetic Manipulation of Cell Migration with High Spatiotemporal Resolution Using Lattice Lightsheet Microscopy

Tang, W.-C.; Liu, Y.-T.; Yeh, C.-H.; Lin, Y.-L.; Lin, Y.-C.; Hsu, T.-L.; Gao, L.; Chen, P.\* , and Chen, B.-C.\*

Academic Sinica, Research Center for Applied Sciences  
*Communications Biology*, 5, 879  
DOI:10.1038/s42003-022-03835-6 (2022)

Integration of the stimulation light source into lattice lightsheet microscopy allows us to conduct optogenetic experiment with precisely three-dimensional activation for a long time with no noticeable phototoxicity. We also show that the membrane ruffling with EGFR-CRY2olig-mApplex3 can be triggered at different locations within the same cell sequentially with subcellular resolution, where the activated cell can recover



after 30 minutes for next stimulation. We can continuously guide the cell migration for up to 6 hours, where 463 imaging volumes are collected, without noticeable damage to the cell. In summary, the 3D activation capability of our approach opens the opportunity for optogenetic activation of single cells in small animal models.



# 林鈺容

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## 個人簡介

林鈺容博士於 2014 年自國立陽明大學生理所取得博士學位，隨後進入國立清華大學化工系擔任博士後研究員。在博士與博士後期間，林博士累積了豐富的跨領域研究經驗，從生理學延伸至藥物傳遞與奈米醫學的應用。自 2020 年起，林博士於中研院應科中心擔任助研究員，開展以臨床需求為導向的創新研究。林博士所帶領的研究團隊目標為開發先進藥物遞送系統，以重塑與疾病相關的組織微環境，來提升治療成效。近年來，他們的研究成果已發表於《ACS Nano》、《Biomaterials》、《Chemical Engineering Journal》等國際頂尖期刊。代表性成果包括：設計以薄荷醇為基礎的遞送平台，誘導脂肪細胞棕化以治療肥胖與代謝性疾病；開發具產氫能力的奈米顆粒，以調控發炎反應並促進組織修復；建構可改善腫瘤免疫微環境的奈米藥物，以提升免疫治療的效應。此外，林博士也開發出具導電性的傷口敷料，以加速組織癒合與即時監測癒合進程。這些研究工作獲得多項重要資源的支持，包括國科會「2030 跨世代年輕學者計畫」，並榮獲李昭仁教授生醫工程發展基金會之年輕學者獎的肯定。展望未來，林博士的團隊將持續探索神經與免疫交互作用對腫瘤微環境重塑的潛在影響，並進一步拓展研究方向至再生醫學領域。林博士也將強化跨領域的緊密合作，以期推動團隊的研究成果邁向臨床應用。

## 代表著作

- 1 Ngo, T. L. H., Wang, K. L., Pan, W. Y., Ruan, T.\* **Lin, Y. J.\*** Immunomodulatory prodrug micelles imitate mild heat effects to reshape tumor microenvironment for enhanced cancer immunotherapy. *ACS Nano* 2024, 18, 5632–5646.
- 2 Ruan, T., Fu, C. Y., Lin, C. H., Chou, K. C., **Lin, Y. J.\*** Nanocontroller-mediated dissolving hydrogel that can sustainably release cold-mimetic menthol to induce adipocyte browning for treating obesity and its related metabolic disorders. *Biomaterials* 2023, 297, 122120.
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- 5 Nguyen, N., Lin, Z. H., Barman, S. R. Korupalli, C., Cheng, J. Y., Song, N. X., Chang, Y., Mi, F. L., Song, H. L., Sung, H. W.\* **Lin, Y. J.\*** Engineering an integrated electroactive dressing to accelerate wound healing and monitor noninvasively progress of healing. *Nano Energy* 2022, 99, 107393.

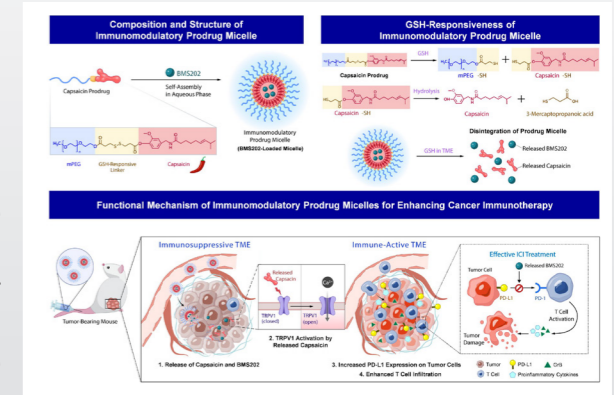
## 研究重點

### Immunomodulatory Prodrug Micelles Imitate Mild Heat Effects to Reshape Tumor Microenvironment for Enhanced Cancer Immunotherapy

Thi-Lan-Huong Ngo, Kuan-Lin Wang, Wen-Yu Pan, Ting Ruan\* and Yu-Jung Lin\*

Research Center for Applied Sciences, Academia Sinica  
*ACS Nano* 2024, 18, 5632–5646.

This study employs capsaicin to chemically stimulate TRPV1, imitating immunomodulatory benefits akin to those induced by mild heat. This involves developing a glutathione (GSH)-responsive immunomodulatory prodrug micelle system to deliver capsaicin and an immune checkpoint inhibitor (BMS202) concurrently. Within the GSH-rich tumor microenvironment (TME), the micelles disintegrate and release capsaicin and BMS202. The released capsaicin activates TRPV1 expressed in the TME, enhancing PD-L1 expression on tumor cell surfaces and promoting T cell recruitment into the TME, rendering it more immunologically active. Meanwhile, the liberated BMS202 blocks immune checkpoints on tumor cells and T cells, activating the recruited T cells and ultimately eradicating the tumors. This innovative strategy represents a comprehensive approach to fine-tune the TME, significantly amplifying the effectiveness of cancer immunotherapy.

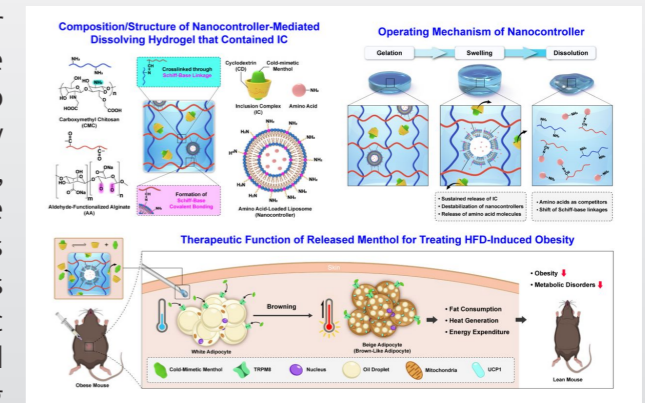


### Nanocontroller-Mediated Dissolving Hydrogel that Can Sustainably Release Cold-Mimetic Menthol to Induce Adipocyte Browning for Treating Obesity and Its Related Metabolic Disorders

Ting Ruan, Chih-Yu Fu, Chih-Hung Lin, Kun-Chi Chou, and Yu-Jung Lin\*

Research Center for Applied Sciences, Academia Sinica  
*Biomaterials* 2023, 297, 122120.

An injectable hydrogel is developed to sustainably deliver cold-mimetic menthol for adipocyte browning. It contains carboxymethyl chitosan and aldehyde-functionalized alginate crosslinked with dynamic Schiff-base linkages, loaded with menthol-cyclodextrin inclusion complexes. Amino acid-loaded liposomes, functioning as nanocontrollers, are grafted onto the hydrogel to make it soluble after the payload release. When injected into obese mice, the hydrogel gradually releases menthol to induce adipocyte browning and increase energy expenditure. The hydrogel networks expand, triggering the grafted liposomes to release amino acids that dissolve the hydrogel. This nanocontroller-mediated dissolving hydrogel is effective for treating obesity and related metabolic disorders without leaving exogenous hydrogel materials inside the body, and thereby preventing any undesired adverse effects.





# 謝東翰

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### 個人簡介

謝東翰任職於本院應科中心之研究技師，專精的項目為計算物理、高速電腦系統建置、與資訊系統維護。他的研究興趣聚焦於生醫影像處理與機器學習，同時也致力於推動該領域的知識和創新。他是台大物理系博士，並已在相關領域的研究計畫中作出貢獻。

他已為應科中心建置了一套高速計算系統，其已應用在本中心與合作者從事第一原理計算以及機器學習等項目，對本中心的研究有顯著貢獻。

他與楊富量老師合作，開發了 Deduction Learning 模型，應用在非侵入式血糖、與無袖帶血壓的量測與估計。作為一個指導老師，他指導了一位博士班學生，將其培養成機器學習新人才。他也曾經審查過國科會研究計畫，同時也是 Diagnostics、Photonics、以及 Sensors (MDPI) 等國際期刊的審稿員。他也在去年本中心主辦的 OPTIC2024 國際研討會中擔任後台系統開發工作，協助舉辦該國際研討會。

他的研究方向將會以機器學習深入生醫影像處理為目標，並且加強跨領域的合作。他將致力於將學術發現轉化為現實世界的應用，確保對學術界和社會產生持久影響。

### 代表著作

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- Wei-Ru Lu, Wen-Tse Yang, Justin Chu, Tung-Han Hsieh, and Fu-Liang Yang, "Deduction learning for precise noninvasive measurements of blood glucose with a dozen rounds of data for model training", Sci. Rep. 12, 6506 (2022).
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### 研究重點

#### PPG signal pattern analysis via deduction learning

Wei-Ru Lu, Wen-Tse Yang, Justin Chu, Tung-Han Hsieh, Fu-Liang Yang

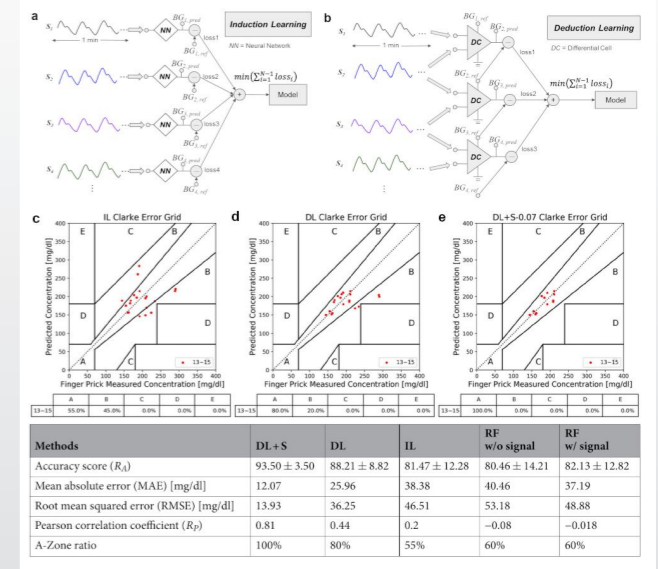
Research Center for Applied Sciences, Academia Sinica  
(A part of work in *Scientific Report* (2022) 12:6506)

Diabetes mellitus (DM) is a chronic condition of abnormally elevated blood glucose level (BGL), which leads to various complications. Currently, reliable BGL measurement utilize invasive methods.

In this work, an attempt of noninvasive blood glucose (NIBG) prediction via correlating photoplethysmo-graphy (PPG) to BGL using deduction learning (DL) was developed. Unlike the traditional induction learning (IL), DL has rules based on our domain knowledge being imposed in the model to guide the learning. For PPG based NIBG, the rule imposed is the assumption of the relation between predicted BGL with its precede BGL, and also the measured PPG signals.

$$DL \leftarrow \sum_{i=2}^N f(S_i, S_{i-1}, BGL_{i-1})$$
$$BGL_k \leftarrow DL(S_k, S_N, BGL_N)$$

Using DL, we successfully trained our model with only a dozen of rounds (1 - 12) of training data, and gave good predictions on BGL for rounds 13 - 15.

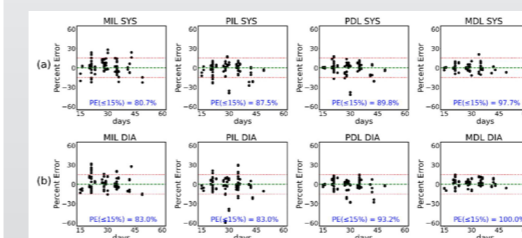
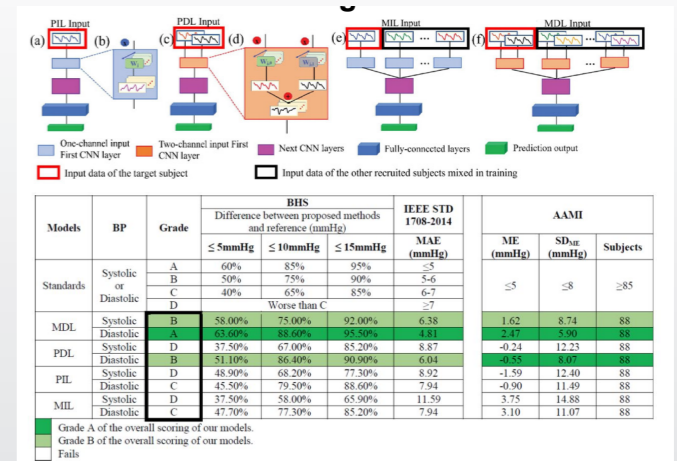


#### Reliable Cuffless Blood Pressure Measurements with 9-mins Personal PPG data and Mixed Deduction Learning

Bitewulign K. Mekonnen, Wei-Ru Lu, Tung-Han Hsieh, Justin Chu, Fu-Liang Yang

Research Center for Applied Sciences, Academia Sinica  
(Scientific Reports 14, 23722 (2024))

Cuffless blood pressure (BP) measurements have long been anticipated. In this work, we developed the Mixed Deduction Learning (MDL) model that only requires 9-mins of personal PPG data and mixed with other PPG data collected from our recruited subjects for training, to attend a 30-plus days of reliable BP prediction without further calibrations. Given our consideration of real-life usage, this technology can be seamlessly translated to commercial applications.



Comparison between Mixed Deduction Learning (MDL), Personalized Deduction Learning (PDL), and traditional Personalized Induction Learning (PIL) and Mixed Induction Learning (MIL). We have demonstrated that MDL attained the best performance and can meet grade A for diastolic and grade B for systolic BP predictions, for BHS, IEEE 1708-2014, and AAMI standards.

# 謝書宜

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## 個人簡介

謝書宜是專業於化學合成的助理研究技師。她的研究主要著重於小分子藥物和金屬奈米粒子的合成，並致力於將該領域的技術整合進本中心的計畫中。她的博士學位是在國立清華大學化學系取得。除了專業技術，謝書宜也負責進行本中心的核心設施建置與維運，提供良好的元件製程與分析服務。此外，她還負責管理本中心同仁的實驗安全及所有實驗室的安全措施。

她目前正在開發自動化化學合成系統，主要目標是應用於小分子藥物研究，並對藥物開發產生影響。

謝書宜積極與不同領域的研究人員合作，並且在多項跨領域研究中作出貢獻。

未來，除了持續加強維護核心設施運作以提供有效的微、奈米製程服務外，謝書宜的研究將集中於深化自動化化學合成並加強跨學科合作。她致力於將學術發現轉化為現實世界的應用，並確保對學術界和社會產生持久影響。

## 代表著作

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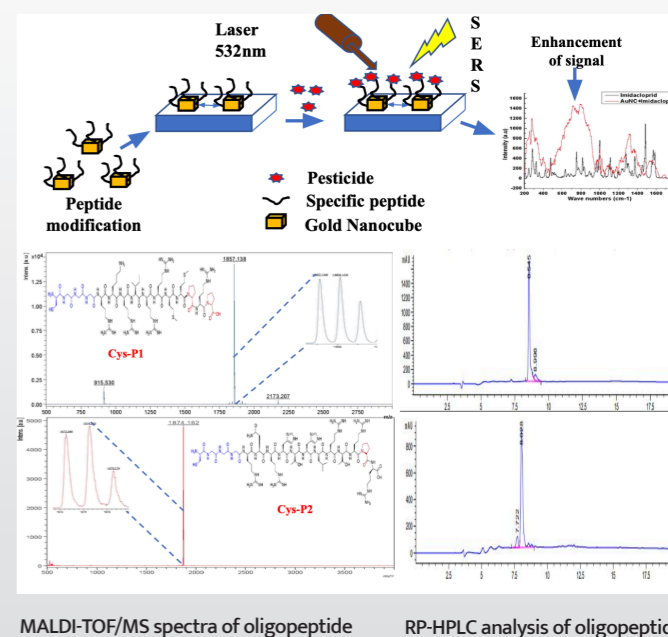
## 研究重點

### Multiple Pesticides Detection by Integrating Synthetic Peptides and Gold Nanoparticles

Tran Thi Anh Hong, Sheng-Hann Wang, Ting-Wei Chang, Pei-Kuen Wei, Shu-Yi Hsieh\*

Research Center for Applied Sciences, Academia Sinica, Taipei 11529, Taiwan

In this study, we attempt to develop a detection system by integrating self-synthesized peptides and gold nanoparticles (AuNPs) that is time-saving and enhances specificity as well as a simple technique. Principally, the surface-enhanced Raman scattering (SERS) technique is applied for pesticide detection, herein, AuNPs can be used as SERS substrate due to its roughened surfaces induces Raman signal enhancement. In addition, oligopeptide sequences CGGGRKRIRRMMPRPS (Cys-P1) and CGGGRNRHTLRTPR (Cys-P2) were found for specific binding with thiocloprid and imidacloprid, respectively, whereas the CGGG fragment helps to bind with AuNPs forming peptide-modified AuNPs. Therefore, Raman signal from the captured pesticides is enhanced, and an improved specificity is also achieved by decreasing non-specific signals. For oligopeptide Cys-P1 and Cys-P2, Rink amide resin was used for Fmoc solid phase peptide synthesis. The purity of Cys-P1-CONH<sub>2</sub> and Cys-P2-CONH<sub>2</sub> was estimated to be about 90% and 92% by reverse phase HPLC (RP-HPLC). Together, Matrix-assisted laser desorption/ionization-time of flight (MALDI-TOF) mass spectrometry (MS) analysis shows the m/z value of Cys-P1-CONH<sub>2</sub> to be 1857.14 and 1858.13; Cys-P2-CONH<sub>2</sub> to be 1873.27 and 1874.26 which contained cis-Proline and trans-Proline isomers in sequence. In future work, we will continuously optimize the peptide-pesticides binding conditions in SERS analysis.

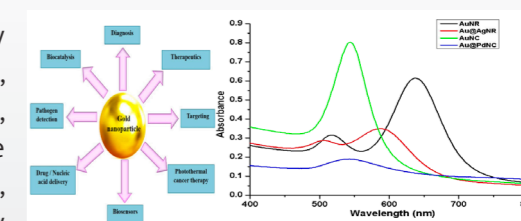


### Various Gold Nanoparticles Synthesis: Property, Morphology and Applications

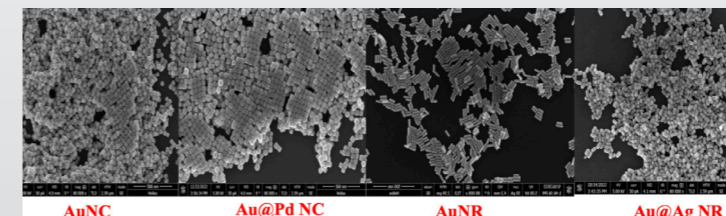
Tran Thi Anh Hong, Shu-Yi Hsieh\*

Research Center for Applied Sciences, Academia Sinica, Taipei 11529, Taiwan

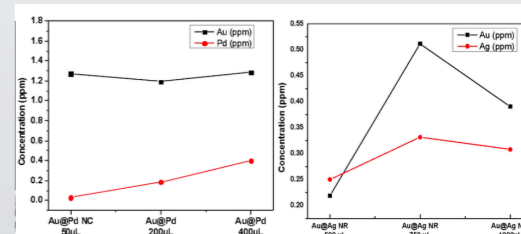
Gold nanoparticles (NPs) have been used in a variety of applications such as diagnosis, therapeutics, targeting, photothermal cancer therapy, biosensors, drug delivery, pathogen detection, and biocatalysis. In RCAS, we synthesize the various AuNPs including AuNCs, Au@Pd NCs, AuNRs, and Au@Ag NRs and provide it to research. Furthermore, by employing the surface-enhanced Raman scattering technique, AuNCs and AuNRs are used as sensitive probes as well as an enhanced signal in SERS. Core-shell Au@Ag NRs with different shell thicknesses of silver will enhance the chemical interface damping (CID) effect. In addition, bimetallic core-shell Au@Pd nanoparticles were applied in enhanced catalytic activity. The particles of AuNPs were characterized by scanning electron microscopy (SEM) and UV-visible spectroscopy, and ICP-OES determined the Au/Ag/Pd mass concentration.



Application of AuNPs



SEM image of the AuNPs immobilized on Si wafer



ICP-OES measurement of Au@PdNC and Au@AgNR

A stylized, light blue plant logo with a vertical stem and two large, rounded leaves, positioned on the left side of the page. The background is a dark blue gradient.

# 綠色科技專題中心

| 研究人員 |

# 朱治偉

## 研究員兼綠色科技專題中心執行長

加州大學洛杉磯分校材料科學與工程系博士 (2006)

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### 個人簡介

朱治偉博士，專注於永續能源研究的研究員。他的研究重點包括高轉換效率的次世代太陽能電池及高能量密度電池，致力於推動能源材料的創新。他在美國加州大學洛杉磯分校 (UCLA) 獲得材料科學與工程博士學位。迄今，朱博士已發表超過 250 篇經同行評審的論文，總引用次數超過 23,000 次 (H 指數：70)，在光伏與能源儲存領域產生了重要的影響。

朱博士主導兩項重大研究計畫，致力於改變可再生能源與能源儲存的未來。第一項計畫專注於開發高效率鈣鈦礦 / 矽串聯太陽能電池，以突破 Shockley-Queisser 效率極限。他的團隊成功克服關鍵的界面挑戰，近期已達成超過 31% 的轉換效率，為更具成本效益與可擴展性的太陽能解決方案奠定基礎。第二項計畫則聚焦於推動固態電池技術，透過設計高離子導電性且具優異熱穩定性的聚合物，提升電池的安全性與能量密度。目前，這些技術已開始規劃應用於實際電池系統，這些研究成果將加速永續能源未來的轉型。

朱博士的未來研究將持續推動高效率太陽能與次世代能源儲存技術的發展，並加強跨領域合作。他致力於將基礎研究轉化為實際應用，發展具可擴展性與永續性的技術，並以此驅動全球向清潔能源的轉型。他的工作將繼續解決可再生能源與電池安全性的關鍵挑戰，確保對學術界與社會產生深遠影響，加速創新能源技術的落地應用，實現更永續的未來。

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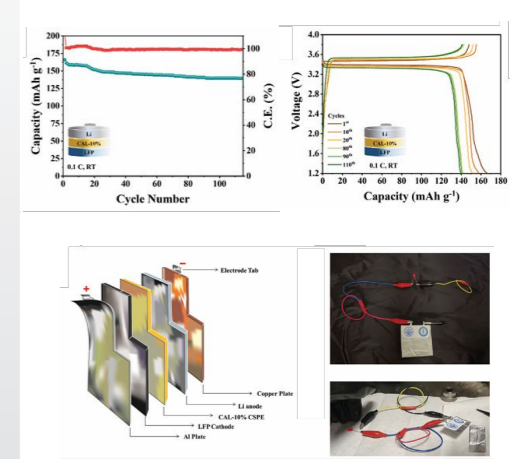
### 研究重點

#### A-LLTO Nanoparticles Embedded Composite Solid Polymer Electrolyte for Room Temperature Operational Li-metal Batteries

Rohan Paste, Yu-Te Chen, Krishna Borde, Atul Dhage, Shih-Sheng Sun, Hong-Cheu Lin, and Chih Wei Chu

Academic Sinica, Research Center for Applied Sciences  
Small, 2024, DOI: 10.1002/sml.202311382

Solid-state batteries (SSBs) are poised to revolutionize energy storage, particularly for electric vehicles and next-generation electronics. While lithium-ion batteries (LIBs) dominate today's market, future energy demands call for safer, more reliable alternatives. This study introduces a novel solid-state electrolyte composed of a self-healing composite solid polymer electrolyte (CSPE) matrix with aluminum-doped ( $\text{Li}_{0.33}\text{La}_{0.56}\text{Ti}_{1.005}\text{Al}_{0.01}\text{O}_3$  (A-LLTO) nanofillers. The optimized CSPE (CAL-10%) achieves a room-temperature ionic conductivity of  $1.1 \times 10^{-3} \text{ S cm}^{-1}$ , facilitated by a percolation network formed by uniformly dispersed A-LLTO nanofillers, enhancing  $\text{Li}^+$  ion transport. A  $\text{LiFePO}_4 \parallel \text{CAL-10\%} \parallel \text{Li CR-2032}$  cell delivers an initial discharge capacity of  $\approx 165 \text{ mAh g}^{-1}$  at 0.1C for 120 cycles with 98.85% coulombic efficiency, demonstrating excellent electrochemical performance. These findings highlight the potential of CSPE-based electrolytes to advance SSB technology for high-performance energy storage applications.

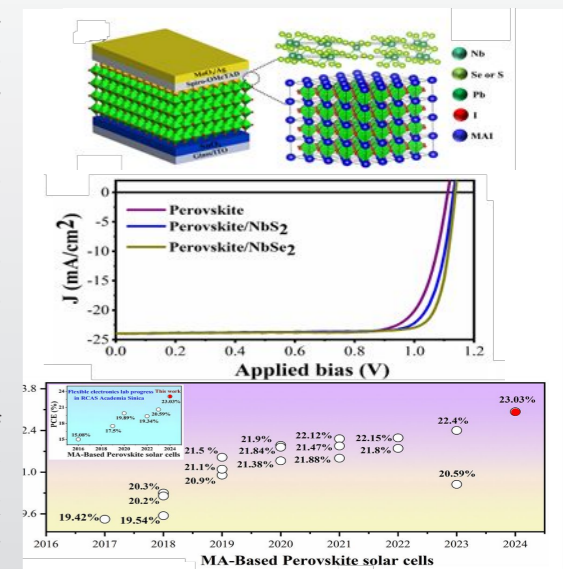


#### Ion mitigation and strain regulation with 2D Semi-Metals for MA-Based perovskite materials in highly efficient solar cells

Chintam Hanmandlu, Soumallya Banerjee, Abhishek Kumar, Zeeshan Alam Ansari, Ramesh Kumar, Yen-Yu Wang, Lin-Chyn Yuan, Shenghan Li, Raman Sanker, Chandra Shekar Gantepogu, You-Yun Wen, Shyam Narayan Singh Yadav, Sumangaladevi Koodathil, Po-Yu-Yang, Chun-Wei Pao, Yu-Jung Lu, Jing-Jong Shyue, Chao-Sung Lai, and ChihWei Chu

Academic Sinica, Research Center for Applied Sciences  
Chemical Engineering Journal, 2025, DOI: 10.1016/j.cej.2024.158070

Achieving high efficiency and stability is crucial for commercializing perovskite solar cells (PSCs). Addressing recombination and voltage losses, particularly at the perovskite/hole-transport layer interface, remains a key challenge. This study introduces a simple surface modification strategy using 2D semi-metallic nanoparticles of  $\text{NbSe}_2$  and  $\text{NbS}_2$  to passivate surface defects. Their divalent anions ( $\text{Se}^{2-}$  and  $\text{S}^{2-}$ ) form strong coordination bonds, reducing trap densities and extending charge carrier lifetime. Additionally, hydrogen bond-like interactions with organic cations enhance film stability. PSCs incorporating  $\text{NbSe}_2$  NP passivation achieved an efficiency of 23.03%, an open-circuit voltage ( $V_{oc}$ ) of 1.14 V, and a fill factor exceeding 84%, with significantly improved stability. This work demonstrates an effective inorganic passivation strategy for high-performance PSCs, advancing their commercial viability.



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## 個人簡介

包淳偉博士現為中央研究院應用科學研究中心研究員，國立臺灣大學、陽明交通大學、以及國立東華大學之合聘教授，曾任美國洛杉磯阿拉莫斯國家實驗室理論部博士後研究員。他於普林斯頓大學取得機械與航太工程博士學位，並分別於國立臺灣大學及國立清華大學取得碩士以及學士學位。

包博士專長於計算材料科學，研究涵蓋多尺度模擬、分子動力學與機器學習模型之開發。他於 2022 年發表於《Nature》之研究揭示超高彈性的化學複雜合金，在其 2024 年《Nature Communications》的工作中，包博士利用機器學習模型首次進行該超彈性複雜合金中差排行為之大尺度模擬。

包博士於 2025 年榮獲國科會傑出研究獎，2023 年榮獲有庠科技論文獎，亦曾獲得中研院深耕計畫暨前瞻計畫，與 IUPAC 創新材料獎。他亦積極參與國際社群之學術期刊編輯、研討會籌辦與研究計畫審查等服務。

## 代表著作

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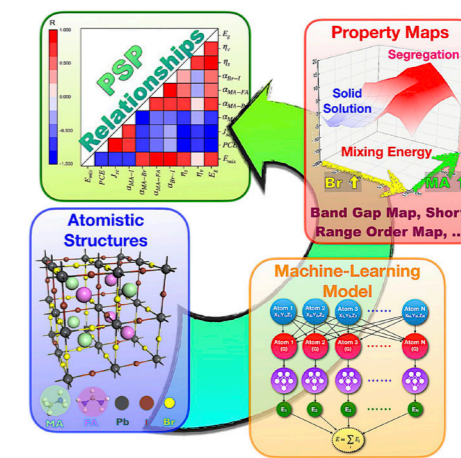
## 研究重點

### Microstructure Maps of Complex Perovskite Materials from Extensive Monte Carlo Sampling Using Machine Learning Enabled Energy Model

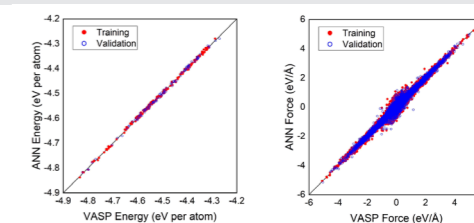
Hsin-An Chen, Ping-Han Tang, Guan-Jie Chen, Chien-Cheng Chang, Chun-Wei Pao\*

*Journal of Physical Chemistry Letters* 12, 3591 (2021)

In this work, we trained an artificial neural network (ANN) potential energy model of the  $MA_yFA_{1-y}Pb(Br_xI_{1-x})_3$  complex perovskite material and investigated the microstructure over the composition space using extensive Monte Carlo simulations. We sampled around  $8.1 \times 10^5$  structures of different site permutations and compositions, identified low energy structures and mapped the structural properties - the mixing energy, SRO parameters, and lattice distortion - over the composition space. Subsequent Pearson correlation analysis revealed the process-structure-property relationship of complex perovskite materials, indicating that the composition lowering the lattice distortion would yield better efficiency because of formation of single solid solution phase.



Extensive Monte Carlo samplings allows mapping of structural properties

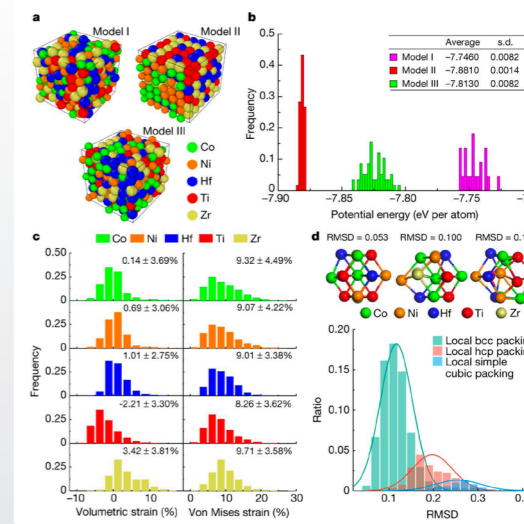


High fidelity of the ANN model to DFT calculations

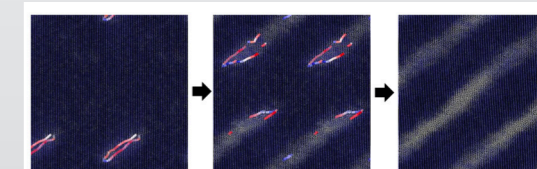
### Multiscale Simulation of Microstructure of Ultra-elastic Complex Alloy

*Nature* 602, 251 (2022) and *Nature Communications* 15, 6782 (2024)

In this work, we collaborated with our experimental collaborators in Hong Kong and decoded the atomistic structure of  $Ni_{25}Co_{25}(HfTiZr)_{50}$  chemically complex alloy using extensive DFT calculations. DFT calculation revealed the judicious chemical ordering at atomic scale helps retain the material stability while undergoing a 11% of atomic size mismatch, which was also confirmed by STEM-EDS experiments. Extensive DFT calculations indicate that each constituent elements is subjected to ~9% of distortion - several times more severe than other high entropy alloys, and is the primary factor leading to the ultraelasticity and Elinvar effect of this extraordinary alloy. A machine learning energy model for large-scale molecular simulation has been trained to further examine its exceptional plastic deformation properties, and we discovered the temperature-dependent microstructure upon loading beyond elastic limit.



Extensive DFT calculations reveal the structural stability and lattice distortion of complex alloy



Plastic deformation from MLMD simulations (Nature Comm, 2024)



# 郭宗枋

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### 個人簡介

郭宗枋博士，專長於有機電子學與有機鹵化鉛混成鈣鈦礦光電子學元件。其研究興趣包括高效能表現的有機 / 高分子電致發光二極體元件、高分子光伏元件、*n*-型有機場效薄膜電晶體、有機光電子學元件獨特的磁場效應。郭博士於美國加州大學洛杉磯分校材料科學與工程學系取得博士學位，並致力於許多跨領域與國際的學術研究工作。

郭博士是全球首先發表表 *p-i-n* 元件結構的鈣鈦礦太陽能電池，這項元件結構也成為目前鈣鈦礦太陽能電池研究領域中主要使用的結構。此外，郭博士亦是全球首先發表使用 *p*-型金屬氧化鎳電極介面層來製作高效能表現的太陽能電池與電致發光二極體元件。這兩項學術成果廣泛應用於鈣鈦礦太陽能電池和固態照明元件的發展。

郭博士與奇美電子公司在有機電致發光二極體元件方面進行產學合作，發展出獨特的有機氧化物 / 鋁複合陰極結構，大幅提升了有機電致發光二極體的效率。他也指導過超過 60 位碩、博士學生，並有許多學生在半導體或有機半導體產業中服務。2012 至 2018 年間，郭博士曾擔任國立成功大學光電科學與工程學系的系主任。目前，他是美國 SPIE 與 OPTICA 的會士。

郭博士目前與未來的研究重點將持續發展高效率的次世代鈣鈦礦 / 矽基疊層式太陽能電池元件，深入研究鈣鈦礦材料在電致發光二極體元件中的獨特介面性質，並持續探討有機光電子學元件的磁場效應，並期望與跨學科領域的研究人員進行合作。

### 代表著作

- 1 Y. Lin, S. -H. Luo, C. -T. Li and T. -F. Guo\*, "Visualizing the "hidden" triplet-triplet fusion process to fluorescence in typical organic/polymer light-emitting diodes" *Adv. Optical Mater.* **13**, 2402111 (2025).
- 2 M. -H. Li, H. -H. Yeh, Y. -H. Chiang, U -S. Jeng, C. -J. Su, H. -W. Shiu, Y. -J. Hsu, N. Kosugi, T. Ohigashi, Y. -A. Chen, P. -S. Shen, P. Chen\*, and T. -F. Guo\*, "Highly efficient 2D/3D hybrid perovskite solar cells via low-pressure vapor-assisted solution process" *Adv. Mater.* **30**, 1804801 (2018). (Highly cited papers in ESI)
- 3 Y. -K. Chih, J. -C. Wang, R. -T. Yang, C. -C. Liu, Y. -C. Chang, Y. -S. Fu, W. -C. Lai, P. Chen, T. -C. Wen, Y. -C. Huang, C. -S. Tsao, and T. -F. Guo\*, "NiOx electrode interlayer and CH3NH2/CH3NH3PbBr3 interface treatment to markedly advance hybrid perovskite-based light-emitting diodes", *Adv. Mater.* **28**, 8687 (2016).
- 4 J. -Y. Jeng, K. -C. Chen, T. -Y. Chiang, P. -Y. Lin, T. -D. Tsai, Y. -C. Chang, T. -F. Guo\*, and P. Chen\* "Nickel oxide electrode interlayer in CH3NH3PbI3 perovskite/PCBM planar-heterojunction hybrid solar cells" *Adv. Mater.* **26**, 4107 (2014). (Highly cited papers in ESI)
- 5 J. -Y. Jeng, Y. -F. Chiang, M. -H. Lee, S. -R. Peng, T. -F. Guo\*, P. Chen\*, and T. -C. Wen "CH3NH3PbI3 perovskite/fullerene planar-heterojunction hybrid solar cells" *Adv. Mater.* **25**, 3727 (2013). (*SPIE Newsroom highlighted*) (Highly cited papers in ESI)

### 研究重點

## Visualizing the "Hidden" Triplet-Triplet Fusion Process to Fluorescence in Typical Organic/Polymer Light-Emitting Diodes

Yulin Lin, Shi-Hong Luo, Chih-Ting Li, and Tzung-Fang Guo

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*Adv. Optical Mater.* **13**, 2402122 (2025)

Fluorescence emission of a typical poly(9,9-dialkylfluorene) derivative (PF GreenB)-based polymer light-emitting diodes (PLEDs) clearly demonstrates that it partially involves the contribution of triplet excitons by the triplet-triplet fusion (TTF) process through measuring the magneto electroluminescence (MEL) responses of devices at different bias conditions and temperatures. The TTF process to fluorescence intrinsically correlates with the concentration, lifetime, and polaron quenching of triplet excitons, as modulated by different bias regimes and conditions. The results in this work unveil the "hidden" component of fluorescence emission, which originates from the fusion of triplet excitons to singlet excitons in typical PLEDs. The results elucidate that TTF of triplet excitons to fluorescence emission can be a practicable mechanism that contributes to enhancing the performance of devices.

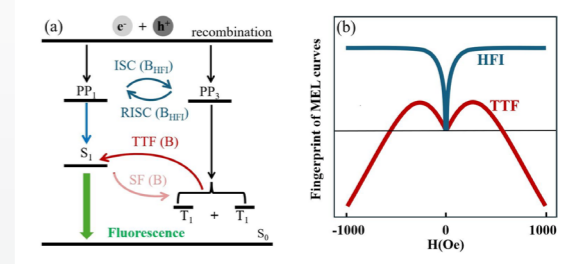


Figure 1. (a) The evolution channel and microscopic processes of ISC(BHFI), RISC(BHFI), SF, and TTF occurred in PF Green B-based devices. (b) Fingerprint MEL curves for HFI and TTF processes.

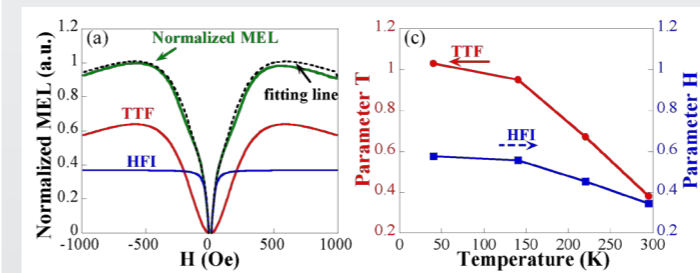
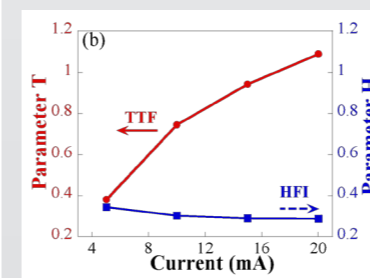


Figure 2. Illustrate the fitting results (a) based on the normalized MEL response measured at 295 K and 5 mA with respect to TTF and HFI intensities. (b) Display the intensity curves of the current-dependent TTF and HFI processes (Parameters T and H) at room-temperature. (c) Show the intensity curves of the temperature-dependent TTF and HFI processes at a fixed 5 mA current.



$$MEL(\text{normalized}) = T \left[ A_1 \frac{B^2}{B^2 + B_{10}^2} - A_2 \frac{B^2}{(|B| + B_{20})^2} \right] + H \frac{B^2}{B^2 + B_{30}^2}$$

MEL fingerprint responses determined by the HFI process can be effectively fitted using Lorentzian functions, while MEL fingerprint responses dominated by the TTF process can be fitted using a combination of Lorentzian and non-Lorentzian functions, where defines the saturation fields of the TTF process at low and high magnetic fields as parameters B10 (248.53 Oe) and B20 (662.71 Oe), respectively. Similarly, B30 (27 Oe) represents the saturation field of the HFI process. The parameters T and H represent the intensity of the TTF and HFI processes, respectively.



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### 個人簡介

張允崇博士在美國北卡羅萊納州立大學電機與電腦工程系取得博士學位，目前為研究員。張博士的專長領域為奈米光子學、電漿子學與光電元件。他的研究興趣主要著重於開發創新的奈米製程技術並推動奈米光子元件的產業化。張博士的研究方向著重發展低成本且高通量的奈米製程，尤其專長開發奈米球相關製程。經過超過 10 年的開發，他的團隊開發且命名的奈米球鏡微影術已經可以用來製作複雜的三維奈米結構陣列來應用於奈米光學元件的商業應用。目前他的團隊也是世界上奈米球相關製程技術的領先團隊。

張博士目前與國內外不同的研究團隊合作研究包括包括電漿子積體光學與超穎介面雷射等不同的題目。另外他也主動參加許多國際學會的工作，目前他是國際學會 SPIE 及 IEEE 的資深會員並且擔任台灣光電學會的教育委員會主任委員。另外他也擔任華人物理學刊的副主編。

未來張博士的研究目標仍以實現奈米元件的商業應用性為主，尤其希望可以開發新一代的綠能光電元件或是可以判斷疾病初期的生物感測平台。

### 代表著作

- 1 C. C. Liu, H. H. Hsiao, Y. C. Chang\*, "Nonlinear Two-photon Pumped Vortex Lasing Based on Quasi-Bound States in the Continuum from Perovskite Metasurface", Science Advances, 2023/05, 9, eadf6649.
- 2 C. Y. Li, C. C. Liu, W. C. Lai, Y. -C. Lan\*, and Y. C. Chang\*, "Quantifying the Plasmonic Generation Rate of Non-Thermal Hot Carriers with an AlGaIn/GaN High-Electron-Mobility Transistor", Advanced Science, 2021/07, 8(13) 2100362.
- 3 C. Y. Lin, C. C. Liu, Y. Y. Chen, K. Y. Chiu, J. D. Wu, B. L. Lin, C. H. Wang, Y. F. Chen, S. -H. Chang\*, and Y. C. Chang\*, "Molecular chirality detection with periodic arrays of three-dimensional twisted metamaterials", ACS Applied Materials & Interfaces, 2021/01, 11(01), 1152–1157.
- 4 M. C. Chou, C. Y. Lin, B. L. Lin, C. H. Wang, S. H. Chang, W. C. Lai, K. Y. Lai, and Y. C. Chang\*, "Polarization-Selecting III-Nitride Elliptical Nanorod Light-Emitting Diodes Fabricated with Nanospherical-Lens Lithography", ACS Nano, 2018/08, 12(08), 8748–8757.
- 5 Y. H. Chien, C. H. Wang, C. C. Liu, S. H. Chang, K. V. Kong, and Y. C. Chang\*, "Large-scale nanofabrication of designed nanostructures using Angled Nanospherical-Lens Lithography for Surface Enhanced Infrared Absorption Spectroscopy", ACS Applied Materials & Interfaces, 2017/07, 9(29), 24917-24925.

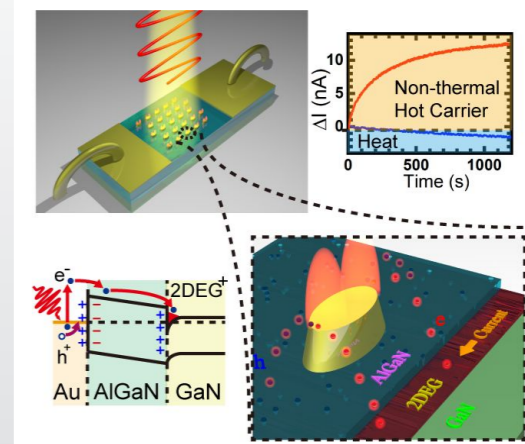
### 研究重點

#### Quantifying the Plasmonic Generation Rate of Non-Thermal Hot Carriers with an AlGaIn/GaN High-Electron-Mobility Transistor

Chun-Yu Li, Chi-Ching Liu, Wei-Chih Lai, Yung-Chiang Lan\*, and Yun-Chorng Chang\*

Academic Sinica, Research Center for Applied Sciences  
Advanced Sciences, 2021, DOI: 10.1002/advs.202100362

Plasmonic generation of hot carriers in metallic nanostructures has attracted much attention due to its great potential in several applications. However, it is highly debated whether the enhancement is due to the hot carriers or the thermal effect. Here, the ability to exclude the thermal effect and detect the generation of non-thermal hot carriers by surface plasmon is demonstrated using an AlGaIn/GaN high-electron-mobility transistor. This ultrasensitive platform, which demonstrates at least two orders of magnitude more sensitivity compared to the previous reports, can detect the hot carriers generated from discrete nanostructures illuminated by a continuous wave light. The quantitative measurements of hot carrier generation also open a new way to optimize the plasmonic nanoantenna design in many applications.



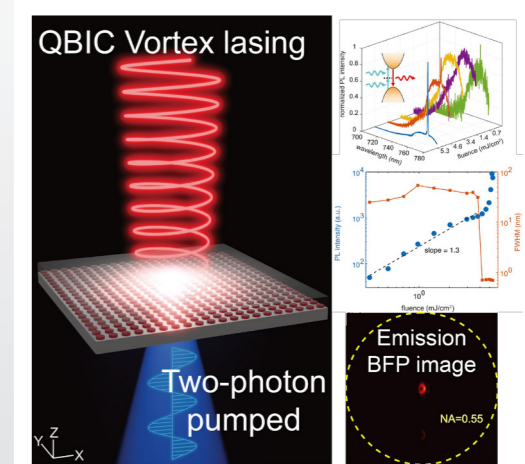
Schematic illustration of hot-electron generation and injection into the 2DEG of an AlGaIn HEMT device

#### Nonlinear Two-photon Pumped Vortex Lasing Based on Quasi-Bound States in the Continuum from Perovskite Metasurface

Chi-Ching Liu, Hui-Hsin Hsiao and Yun-Chorng Chang\*

Academic Sinica, Research Center for Applied Sciences  
Science Advances, 2023, DOI: 10.1126/sciadv.adf6649

The experimental observation of nonlinear two-photon pumped vortex lasing from perovskite metasurfaces is demonstrated for the first time. The vortex lasing beam is based on symmetry-protected quasi-bound states in the continuum (QBIC). The topological charge is estimated to be +1 according to the simulation result. The quality factor and lasing threshold is around 1100 and 4.28 mJ/cm<sup>2</sup>, respectively. Theoretical analysis reveals that the QBIC mode originates from the magnetic dipole mode. The lasing wavelength can be experimentally designed within a broad spectral range by changing the diameter and periodicity of the metasurface. The finite array size effect of QBIC can affect the quality factor of the lasing and be used to modulate the lasing. Results shown in this study can lead to more complex vortex beam lasing from a single chip and new ways to obtain ultrafast modulation of the QBIC lasing via finite array size effect.



Schematic illustration of two-photon pumped vortex lasing based on QBIC

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## 個人簡介

程育人目前是中央研究院應用科學研究中心的副研究員，在史丹佛大學應用物理系獲得博士學位。他的研究興趣涵蓋多個領域，包括過去的 III 族氮化物半導體生長、III 族氮化物 LED 和雷射，最近則涉及二維材料成長和光電器件，及光電化學水分解和電極觸媒。

近期的研究集中在兩個領域：二維材料成長與光電器件，以及水分解的電催化觸媒。

過渡金屬二硫化物半導體材料具有自終止的原子表面結構，強烈的光反應以及優異的電荷傳輸特性，使其成為原子尺度電子與光子器件的有前景材料。這些應用的實現有依賴於晶圓等級的晶體成長。由於與基板的微弱凡德爾作用力，成核通常會導致隨機取向，這使得晶體成長具有挑戰性。他的研究探討了二維材料的生長機制，並開發了可以實現基板晶格引導下的有序成核取向的生長條件，為大面積晶體生長立下基礎。

水分解是從可再生能源產生綠氫的具有吸引力的方法。它的成功高度依賴於電催化觸媒的發展。貴重金屬材料因其高效率廣為人知，但高成本限制了實際應用。他的研究開發了一種過渡金屬組合和超音波化學合成方法，可製備具有非常低過電位，跟 Pt/C 性能相當的高活性水分解電催化觸媒。

## 代表著作

- 1 Pei-Xuan Long, Yung-Yu Lai, Pei-Hao Kang, Chi-Huang Chuang and Yuh-Jen Cheng\*, "High photoresponsivity MoS<sub>2</sub> phototransistor through enhanced hole trapping HfO<sub>2</sub> gate dielectric", *Nanotechnology* 35, 025204 (2024).
- 2 Chi-Huang Chuang, Pei-Hao Kang, Yung-Yu Lai, Cheng-Hung Hou, Wei-Che Tseng, Yan-Jia Huang, Mu-Huai Fang, Jing-Jong Shyue, Chao-Cheng Kaun, and Yuh-Jen Cheng\*, "Highly Active NiO-Ni(OH)<sub>2</sub>-Cr<sub>2</sub>O<sub>3</sub>/Ni Hydrogen Evolution Electrocatalyst through Synergistic Reaction Kinetics", *ChemSusChem* 2023, e202300820.
- 3 Chi-Huang Chuang, Pei-Hao Kang, Yung-Yu Lai, Cheng-Hung Hou, and Yuh-Jen Cheng\*, "Junction Engineering in Si Photoanode for Efficient Photoelectrochemical Water Splitting," *ACS Appl. Energy Mater.* 2022, 5, 7, 8483–8491 (2022).
- 4 Yung-Yu Lai, Chi-Huang Chuang, Yen-Wei Yeh, Cheng-Hung Hou, Shih-Chieh Hsu, Yi Chou, Yi-Chia Chou, Hao-Chung Kuo, YewChung Sermon Wu, and Yuh-Jen Cheng\*, "Substrate Lattice Guided MoS<sub>2</sub> Crystal Growth: Implications for van der Waals epitaxy", *ACS Appl. Nano Mater.* 4, 4930–4938 (2021).
- 5 Yung-Yu Lai, Yen-Wei Yeh, An-Jye Tzou, Yi-Yuan Chen, YewChung Sermon Wu, Yuh-Jen Cheng\*, and Hao-Chung Kuo\*, "Dependence of Photoresponsivity and On/Off Ratio on Quantum Dot Density in Quantum Dot Sensitized MoS<sub>2</sub> Photodetector", *Nanomaterials* 2020, 10, 1828.

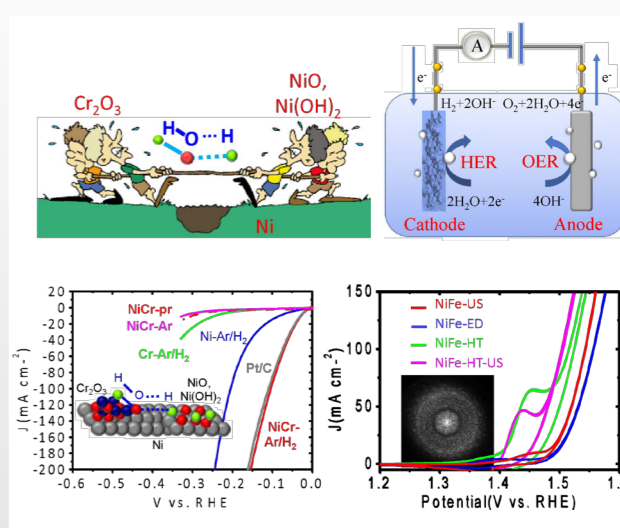
## 研究重點

### Noble-metal-free Electrocatalyst for Water Splitting

Chi-Huang Chuang, Pei-Hao Kang, Chao-Cheng Kaun, and Yuh-Jen Cheng

*ChemSusChem* 2023, e202300820, doi.org/10.1002/cssc.202300820

Electrocatalyst with high catalytic activity are crucial for converting renewable electricity to storable hydrogen fuel. Noble-metal-based materials, e.g. Pt, IrO<sub>2</sub>, RuO<sub>2</sub>, has been the well known highly efficient catalysts. This work focuses on developing noble metal free electrocatalysts for oxygen and hydrogen evolution reaction (OER and HER). This study has developed a HER electrocatalyst consisting of transition metal composition NiOx-Cr<sub>2</sub>O<sub>3</sub>/Ni, showing high activity comparable with Pt/C with low overpotential of -27, and -103, mV at current density of -10, -100 mA cm<sup>-2</sup>. The high activity is attributed to the synergistic effect between NiOx/Ni and Cr<sub>2</sub>O<sub>3</sub> in breaking OH-H bond and forming sites with low H\* adsorption energy to promote H\* to H<sub>2</sub> evolution. This study also developed an ultrasonic deposition to fabricate a NiFe OER electrocatalyst. Ultrasound irradiation in solution increases mixing, dispersion, and reaction, resulting in a well-mixed amorphous catalyst with highly dispersed active sites. Combining hydrothermal and ultrasonic deposition, this work demonstrated a OER electrocatalyst with low overpotential of 220 mV at 10 mA cm<sup>-2</sup> current density.

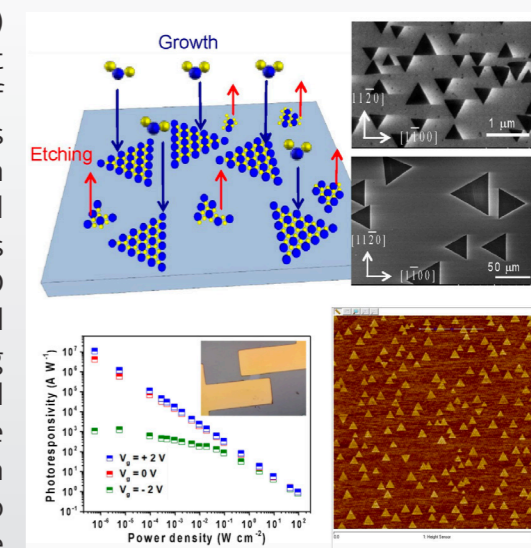


### 2D Semiconductor Crystal Growth and Photonic Devices

Chi-Huang Chuang, Yung-Yu Lai, Pei-Xuan Long, and Yuh-Jen Cheng

*ACS Appl. Nano Mater.* 2021, doi.org/10.1021/acsnm.1c00469

2D transition metal dichalcogenide (TMDC) semiconductor is an emerging material with great potential in novel device applications. The epitaxy of 2D crystal is challenging due to the weak van der Waals interaction with substrate, often resulting in random nucleation orientation and grain boundaries. Crystal growth is critically decided from nucleation. This studies the mechanism of 2D material nucleation on a 3D material substrate and the conditions to obtain aligned nuclei. Nucleation involves reactions not only among precursors but also with substrate surface that are full of unbounded dangling bonds. Proper intermediate steps can lead to a final 2D crystal nucleation with orientation guided by substrate lattice. This work also studies the device applications of 2D materials. Charge carriers in atomic layer thickness are highly sensitive to external electric field modulation yet protected by dangling bond free surface. This study demonstrated a field effect phototransistor with very large photoresponsivity of  $1.1 \times 10^7$  A W<sup>-1</sup> at low illumination intensity.



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### 個人簡介

呂宥蓉博士現為中央研究院應用科學研究中心副研究員，同時合聘於國立台灣大學擔任應用物理所副教授。於 2013 年獲得國立清華大學物理博士學位，並於 2015 至 2017 年間在加州理工學院擔任博士後研究員。呂博士是知名的材料物理學家，專精於主動電漿子學、奈米光學與超穎介面。她的研究重點在於開發陶瓷電漿子奈米元件，在奈米尺度進行光的收集、產生與操控。

她的代表性研究成果包括發現陶瓷電漿子材料（例如導電過渡金屬氮化物 TiN、HfN、NbN、ZrN、NbTiN）中的新特性。近年來，她發現了多種利用等電漿子奈米結構來增強奈米元件能量轉換效率的獨特機制，這些機制透過設計局部強電磁場，提升奈米尺度的光與物質相互作用實現超靈敏的超導單光子偵測器。相關研究目前也跟台積電積極合作中。她對於奈米光電元件領域充滿熱忱，並曾擔任 GNP、MRS Fall、META、SPIE O+P 及 CLEO Pacific Rim 等國際研討會的主席、共同主席與委員。2021 年，她獲選為 SPIE Women in Optics Planners 之一。她屢獲殊榮，並在國際奈米光學會議上受邀演講超過 50 次。此外，她亦積極培育人才，指導超過 65 名研究生、研究助理及博士後研究員，為奈米光學領域培育新秀。

呂博士現為三個國際期刊 APL Quantum、Advanced Photonics 及 Journal of Lightwave Technology 的期刊副主編。她曾獲得多項台灣學術獎項，包括中研院前瞻計畫 (2018)、青年光電工程獎 (2020)、SPIE 資深會員 (2023)、美國材料學會年輕學者傑出發表 (2024)、未來科技獎 (2024)、IEEE 資深會員 (2025) iSPN 年輕學者獎 (2025)。她的研究成果發表於 Nature Communications、Nano Letters、ACS Nano、ACS Photonics、Nature Nanotechnology 及 Science 等高影響力國際期刊。

### 代表著作

- 1 Yen-Yu Wang<sup>#</sup>, Xing-Hao Lee<sup>#</sup>, Chiung-Han Chen, Linchyn Yuan, Yin-Ti Lai, Tzu-Yu Peng, Jia-Wern Chen, Chu-Chen Chueh<sup>\*</sup>, and Yu-Jung Lu<sup>\*</sup>, Plasmon-Enhanced Exciton Re-localization in Quasi-2D Perovskites for Low-Threshold Room-Temperature Plasmonic Lasing. *Science Advances* 11, eadu6824 (2025)
- 2 Tzu-Yu Peng<sup>#</sup>, Jason Lynch<sup>#</sup>, Jing-Wei Yang, Yen-Yu Wang, Xing-Hao Lee, Ben R. Conran, Clifford McAleese, Deep Jariwala<sup>\*</sup>, and Yu-Jung Lu<sup>\*</sup>, Polariton-Mediated Ultrafast Nonlinear Energy Transfer in a van der Waals Superlattice. *ACS Nano* 19, 8152–8161 (2025)
- 3 Wei-Ren Syong, Jui-Han Fu, Yu-Hsin Kuo, Yu-Cheng Chu, Mariam Hakami, Tzu-Yu Peng, Jason Lynch, Deep Jariwala, Vincent Tung, and Yu-Jung Lu<sup>\*</sup>, Enhanced Photogating Gain in Scalable MoS<sub>2</sub> Plasmonic Photodetectors via Resonant Plasmonic Metasurfaces. *ACS Nano* 18, 5446–5456 (2024)
- 4 Jing-Wei Yang, Tzu-Yu Peng, Daniel D. A. Clarke, Frank Daniel Bello, Jia-Wern Chen, Hao-Chen Yeh, Wei-Ren Syong, Chi-Te Liang, Ortwin Hess<sup>\*</sup>, and Yu-Jung Lu<sup>\*</sup>, Nanoscale Gap-Plasmon-Enhanced Superconducting Photon Detectors at Single-Photon Level. *Nano Letters* 23, 11387–11394 (2023)
- 5 Hao-Yu Lan, Yu-Hung Hsieh, Zong-Yi Chiao, Deep Jariwala, Min-Hsiung Shih, Ta-Jen Yen, Ortwin Hess, and Yu-Jung Lu<sup>\*</sup>, Gate-Tunable Plasmon-Enhanced Photodetection in a Monolayer MoS<sub>2</sub> Phototransistor with Ultrahigh Photoresponsivity. *Nano Letters* 21, 3083–3091 (2021).

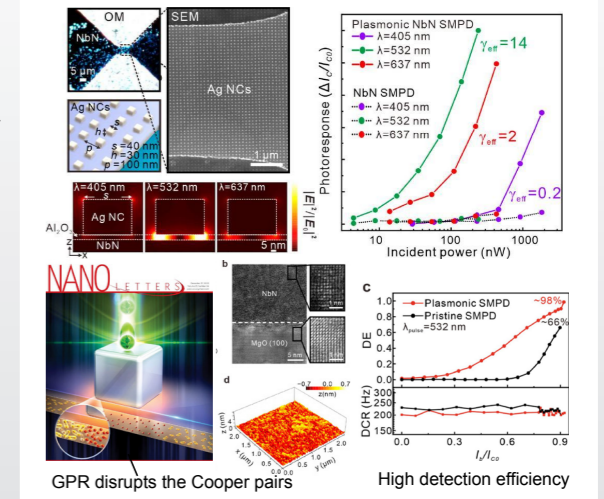
### 研究重點

#### Nanoscale Gap-Plasmon-Enhanced Superconducting Photon Detectors at Single-Photon Level

Jing-Wei Yang, Tzu-Yu Peng, Daniel D. A. Clarke, Frank Daniel Bello, Jia-Wern Chen, Hao-Chen Yeh, Wei-Ren Syong, Chi-Te Liang, Ortwin Hess,<sup>\*</sup> and Yu-Jung Lu<sup>\*</sup>

Research Center for Applied Sciences, Academia Sinica  
*Nano Letters* 23, 11387–11394 (2023)

With a growing demand for detecting light at the single-photon level in various fields, researchers are focused on optimizing the performance of superconducting single-photon detectors (SSPDs) by using multiple approaches. However, input light coupling for visible light has remained a challenge in the development of efficient SSPDs. To overcome these limitations, we developed a novel system that integrates NbN superconducting microwire photon detectors (SMPDs) with gap-plasmon resonators to improve the photon detection efficiency to 98% while preserving all detector performance features, such as polarization insensitivity. The optimized detection efficiency can be attributed to the gap plasmon mode that enhances the light-matter interaction, leading to the efficient disruption of Cooper pairs and the consequent breakdown of the superconducting state. These findings open new opportunities for ultrasensitive single-photon detection in areas like quantum information processing, quantum optics, imaging, and sensing at visible wavelengths.

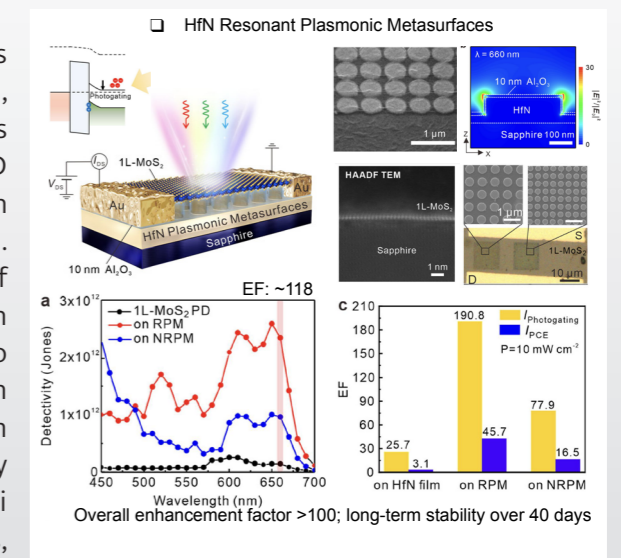


#### Enhancing Photogating Gain in Scalable MoS<sub>2</sub> Plasmonic Photodetectors via Resonant Plasmonic Metasurfaces

Wei-Ren Syong, Jui-Han Fu, Yu-Hsin Kuo, Yu-Cheng Chu, Mariam Hakami, Tzu-Yu Peng, Jason Lynch, Deep Jariwala, Vincent Tung, and Yu-Jung Lu<sup>\*</sup>

Research Center for Applied Sciences, Academia Sinica  
*ACS Nano* 18, 5446–5456 (2024)

Absorption of photons in atomically thin materials has become a challenge in the realization of ultrathin, high-performance optoelectronics. While numerous schemes have been used to enhance absorption in 2D semiconductors, such enhanced device performance in scalable monolayer photodetectors remains unattained. Here, we demonstrate wafer-scale integration of monolayer single-crystal MoS<sub>2</sub> photodetectors with a nitride-based resonant plasmonic metasurface to achieve a high detectivity of  $2.58 \times 10^{12}$  Jones with a record-low dark current of 8 pA and long-term stability over 40 days. Considering the compatibility of 2D semiconductors and hafnium nitride with the Si CMOS process and their scalability across wafer sizes, our results facilitate the smooth incorporation of 2D semiconductor-based photodetectors into the fields of imaging, sensing, and optical communication applications.



# 方牧懷

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## 個人簡介

方牧懷博士現為中央研究院應用科學研究中心的助理研究員。他的研究興趣專注應用於「固態電池」、「短波紅外線光感測器」和「紅外線發光二極體」的材料設計。

他開發了一種新型過飽和驅動共沉澱合成法，用於合成鹵化物固態電解質，並應用於固態電池。此方法具備同時實現「調控固態電解質組成」與「大規模生產」的潛力，不僅止於學術研究層面，亦同時考量實際產業化過程中穩定量產的挑戰。他與中央研究院應用科學研究中心林時彥博士，合作開發了基於量子點工藝的石墨烯場效電晶體光感測器元件，這種元件無須冷卻且可於室溫下對 900–1700 nm 紅外線光源產生光電流訊號，偵測率 (detectivity) 可達  $\sim 10^{12} \text{ Hz}^{1/2} \text{ W}^{-1}$ 。他還與台灣大學化學系梁文傑教授，合作開發可用於發光二極體的永續量子點-類玻璃體的奈米高分子複合材料，此種複合材料能以機械式與化學式方式進行回收，在不破壞含鎘量子點的結構與光學性質情況下，分離鎘元素達 >99.9%，並得將回收的高分子與量子點重複利用，實現永續循環再利用。

他未來的研究旨在強化鹵化物固態電解質的液態合成法，證明此方法能實現「調控固態電解質組成」與「大規模生產」。他也將透過跨領域合作提高量子點短波紅外線光感測器的性能和化學穩定性，並將上述學術研究實際應用於現實生活。

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- 2 Bilo, J. A. V.; Chang, C.-K.; Chuang, Y.-C.; Fang, M.-H.\* Coprecipitation Strategy for Halide-Based Solid-State Electrolytes and Atmospheric-Dependent In Situ Analysis. *ACS Appl. Mater. Interfaces* 2024, 16, 27394–27399.
- 3 Jhang, A.-T.; Tsai, P.-C.; Tsai, Y.-T.; Lin, S.-Y.\*; Fang, M.-H.\* Quantum-Dots-in-Double-Perovskite for High-Gain Short-Wave Infrared Photodetector. *Adv. Opt. Mater.* 2024, 12, 2401252.
- 4 Huang, P.-Y.; Zhang, Y.-Y.; Tsai, P.-C.; Chung, R.-J.; Tsai, Y.-T.; Leung, M.-k.; Lin, S.-Y.\*; Fang, M.-H.\* Interfacial Engineering of Quantum Dots–Metal-Organic Framework Composite toward Efficient Charge Transport for Short-Wave Infrared Photodetector. *Adv. Opt. Mater.* 2024, 12, 2302062.
- 5 Tsai, Y.-T.; Leśniewski, T.; Majewska, N.; Kamiński, M.; Barzowska, J.; Liu, E.-P.; Chen, W.-T.; Mahlik, S.\*; Fang, M.-H.\* Pressure/Temperature-Assisted Crystallographic Engineering—A Strategy for Developing the Infrared Phosphors. *Chem. Eng. J.* 2024, 490, 151596.

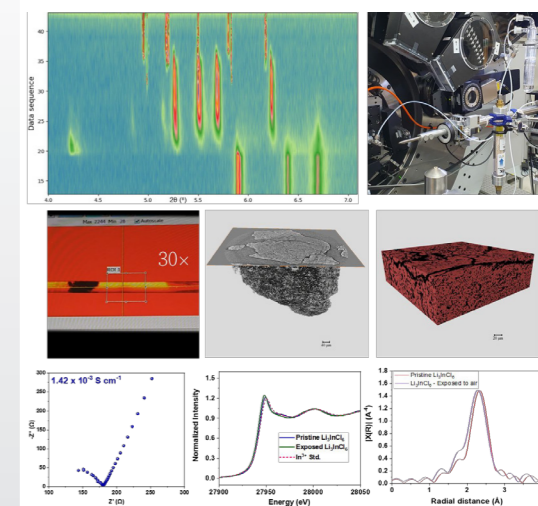
## 研究重點

### Pioneering Wet Chemical Synthesis Route for Halide Solid-State Electrolytes with In-situ Analyses

Josanelle Angela V. Bilo, Saddam Shaikh, and Mu-Huai Fang\*

*ACS Appl. Mater. Interfaces* 2024, 16, 27394–27399.

Solid-state batteries have been pivotal in the development of energy-storage devices. In the continuous pursuit of an energy-efficient alternative to the energy-intensive mechanochemical process, we developed a modified solution-based synthesis strategy for synthesizing halide-based solid-state electrolytes (SSEs) that potentially warrant both structural control and commercial scalability. In this study, we utilize our method to synthesize  $\text{Li}_3\text{InCl}_6$  SSE with high ionic conductivity of  $1.42 \times 10^{-3} \text{ S cm}^{-1}$ , comparable to traditionally prepared counterparts. We also use this method to first synthesize the pure phase  $\text{Na}_3\text{InCl}_6$  SSE, which shows two orders of magnitude ( $10^{-6} \text{ S cm}^{-1}$ ) higher than the ionic conductivity reported in the literature. Through the in-situ synchrotron X-ray diffraction technique, we unveil the stability mechanisms and rapid chemical reactions of these SSE under dry Ar, dry  $\text{O}_2$ , and high-humidity atmosphere, which were not previously reported. These works addressed critical challenges in structural engineering and sustainable mass production and provided insights into chemical reactions under real-world conditions.



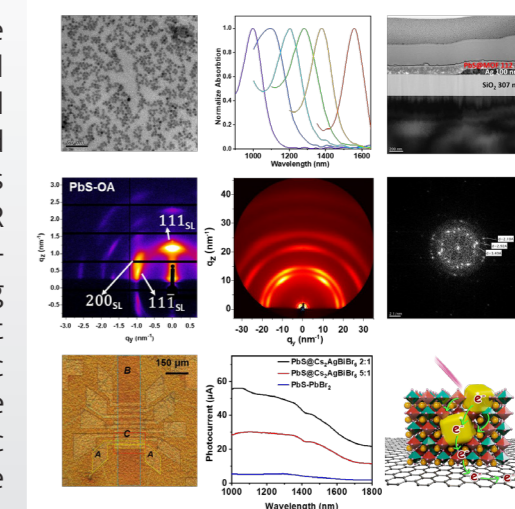
### Cooling-Free Room-Temperature-Operable Short-Wave Infrared Photodetector

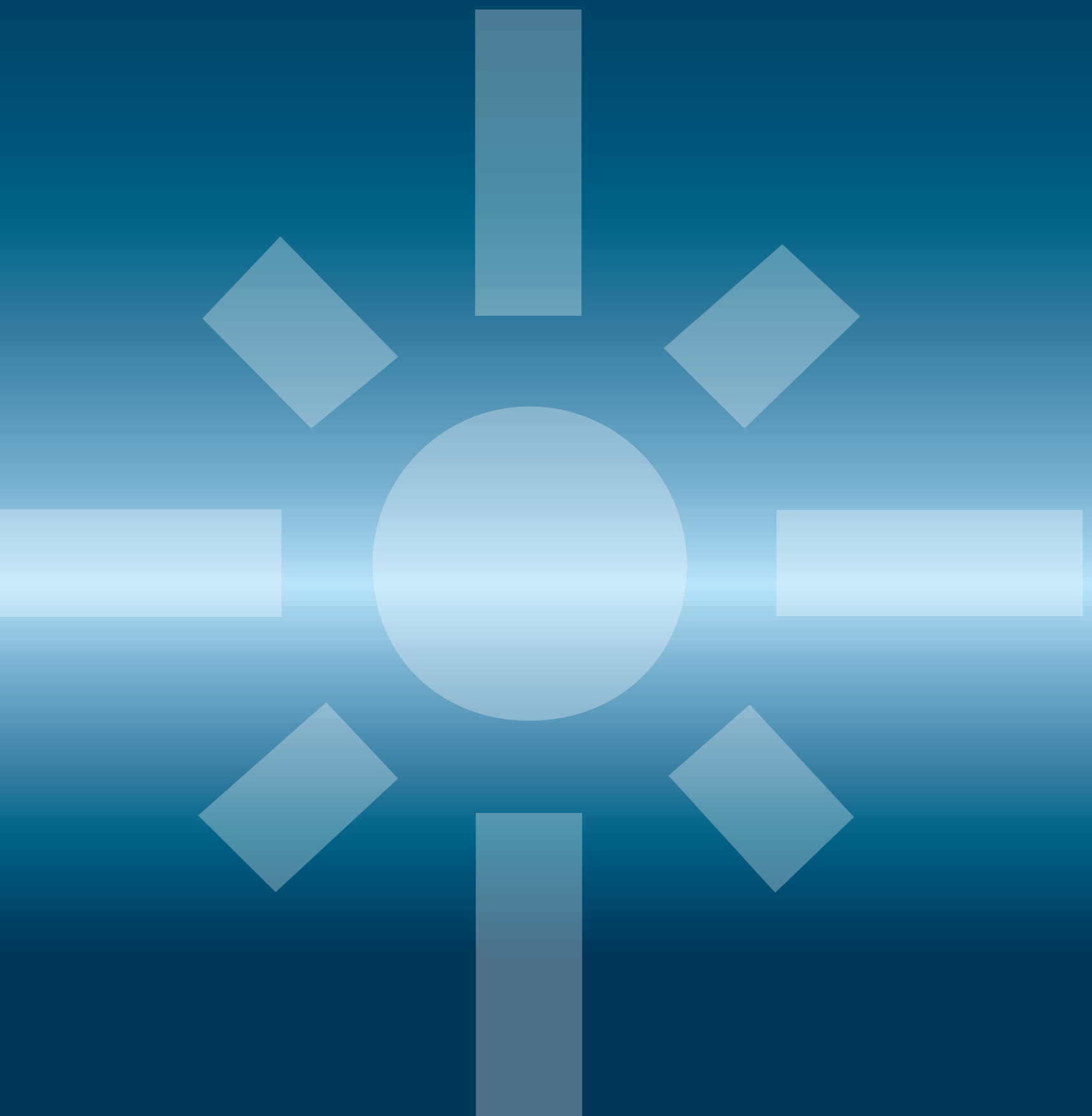
An-Ting Jhang, Po-Yu Huang, Po-Cheng Tsai, Shih-Yen Lin\*, and Mu-Huai Fang\*

*Adv. Opt. Mater.* 2024, 12, 2401252.

*Adv. Opt. Mater.* 2024, 12, 2302062.

Short-wave infrared (SWIR) photodetectors have attracted great attention in the fields of artificial intelligence, machine learning, food analysis, biological detection, etc. However, the cooling requirements and high production costs of compound semiconductors have hindered the practical application of these SWIR photodetectors. Here, we design a cooling-free room-temperature-operable SWIR photodetector by combining the SWIR quantum dots (QDs) and graphene field-effect transistors (FETs). The QDs in which the characteristic absorption peak can be tuned in 900–1700 nm. The composites that QDs hybrid with the metal-organic framework (MOF) and halide-based double perovskite (DP) are demonstrated. In QD@MOF, the responsivity and detectivity of the QD@MOF device are  $301 \text{ A/W}$  and  $1.49 \times 10^{10} \text{ cm Hz}^{1/2} \text{ W}^{-1}$ , respectively. The chemical stability is significantly enhanced compared to the non-hybrid one. By contrast, in the QD@DP, the responsivity and detectivity of QD@DP graphene FET are  $15000 \text{ A/W}$  and  $1.31 \times 10^{12} \text{ cm Hz}^{1/2} \text{ W}^{-1}$ , respectively, significantly promoted compared to the non-hybrid device. This research provides insight into developing energy-saving QD-based SWIR photodetectors.





# 量子光電專題中心

| 研究人員 |



# 張文豪

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### 個人簡介

張文豪博士，目前為中央研究院特聘研究員。他於 2001 年在國立中央大學物理系取得物理博士學位。完成四年博士後研究後，張博士於 2005 年加入國立交通大學電子物理系，擔任助理教授，並自 2012 年起晉升為正教授，於 2018 年獲聘為特聘教授。張博士於 2020 年加入中央研究院應用科學研究中心，並擔任量子光電專題中心執行長。

張博士的研究領域包括半導體奈米材料的光 - 物質交互作用、半導體量子光學以及二維層狀材料。他發表 (共同) 超過 150 篇期刊論文，並累積被引用超過 14,000 次，H 指數為 53。

在學術榮譽方面，張博士曾獲得國科會吳大猷紀念獎 (2010 年)、中山學術文化基金會中山學術獎 (2018 年)、國科會傑出研究獎 (2018 年)、全球華人物理與天文學會亞洲成就獎 (Robert T. Poe Prize) 以及台灣物理學會會士 (2020 年) 等殊榮。

### 代表著作

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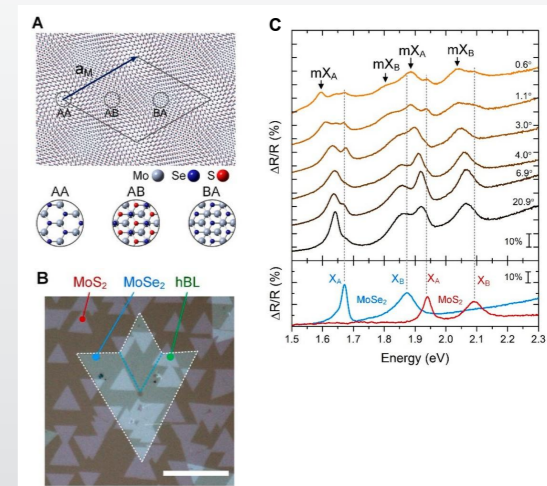
### 研究重點

#### Remarkably Deep Moiré Potential for Intralayer Excitons in MoSe<sub>2</sub>/MoS<sub>2</sub> Twisted Heterobilayers

Bo-Han Lin, Yung-Chun Chao, I-Ta Hsieh, Chih-Piao Chuu, Chien-Ju Lee, Fu-Hsien Chu, Li-Syuan Lu, Wei-Ting Hsu, Chun-Wei Pao, Chih-Kang Shih, Jung-Jung Su, and Wen-Hao Chang

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Department of Electrophysics, National Yang Ming Chiao Tung University  
Nano Letters 2023, DOI:10.1021/acs.nanolett.2c04524

A moiré superlattice formed in twisted van der Waals bilayers can be a new tuning knob for creating new electronic and excitonic states in 2D materials. However, quantifying the moiré potential for excitons is nontrivial. By creating a large ensemble of MoSe<sub>2</sub>/MoS<sub>2</sub> heterobilayers with a systematic variation of twist angles, we map out the minibands of interlayer and intralayer excitons as a function of twist angles, from which we determine the moiré potential for excitons. Surprisingly, the moiré potential depth for intralayer excitons is up to ~130 meV, comparable to that for interlayer excitons. The remarkably deep intralayer moiré potential is understood within the framework of structural reconstruction within the moiré unit cell.



A. Moiré pattern formed by MoS<sub>2</sub> and MoSe<sub>2</sub> heterobilayer. B. Optical microscope image of stacked heterobilayers grown by CVD. C. Reflectance spectra of intralayer moiré exciton states.

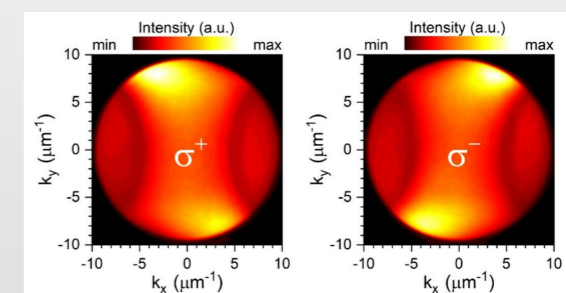
#### Exciton-Polariton Valley Hall Effect in Monolayer Semiconductors on Plasmonic Metasurface

Chien-Ju Lee, Hsin-Che Pan, Fatemeh HadavandMirzaee, Li-Syuan Lu, Fei Cheng, Tsing-Hua Her, Chih-Kang Shih and Wen-Hao Chang

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ACS Photonics 2025, DOI: 10.1021/acsp Photonics.4c01554

Excitons in monolayer transition metal dichalcogenides (TMDs) possess the valley degree of freedom (DOF), which is regarded as a pseudospin (in addition to charge and spin DOF) and can be addressed optically by using polarized light. By placing monolayer TMDs on a plasmonic metasurface to enable strong coupling between excitons and surface plasmon polaritons (SPPs), we report here the observation of valley resolved polaritons in momentum space and a large separation in real space. The directional coupling of valley polaritons originated from the intrinsic spin-momentum locking associated with SPPs, resembling a photonic version of the valley Hall effect for polaritons.

The spatially routed valley polaritons provide a unique pathway for transporting and detecting the valley DOF through circular polarization of light for valleytronic applications.



Far-field separation of valley polariton emission in k-space. The k-space imaging of σ<sup>+</sup> (left) and σ<sup>-</sup> (right) PL from WS<sub>2</sub> on nanogrooves.

# 施閔雄

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### 個人簡介

施閔雄博士目前是中央研究院應用科學研究中心 (RCAS) 的研究員。他在南加州大學 (USC) 電機工程系取得博士學位，其研究興趣集中在光子晶體雷射、二維材料光源元件和表面電漿子元件。

自從加入 RCAS 以來，施博士團隊開發了用於矽和 III-V 半導體元件的奈米製造技術，並製作及研發了 III-V 半導體量子點、量子井和二維材料的光子晶體微型共振腔雷射和奈米表面電漿子光源元件，以實現從紫外線到紅外線波長範圍的不同功能性之光源。

目前其實驗室主要研發並優化二維半導體與金屬電極之間的界面特性，以實現電驅動的二維半導體 LED 和共振腔雷射元件，並將推動二維半導體材料未來應用在發光元件及積體光路系統之可能性。在學術服務方面，施閔雄博士除擔任國際期刊的審稿人以外，還曾經擔任 Optics & Photonics Taiwan, the International Conference (OPTIC) 2024, the 8th International Conference on Surface Plasmon Photonics (SPP8) 2017 及 the 9th International Conference on Nanophotonics (ICNP) 2016 會議的組織委員會主席。

### 代表著作

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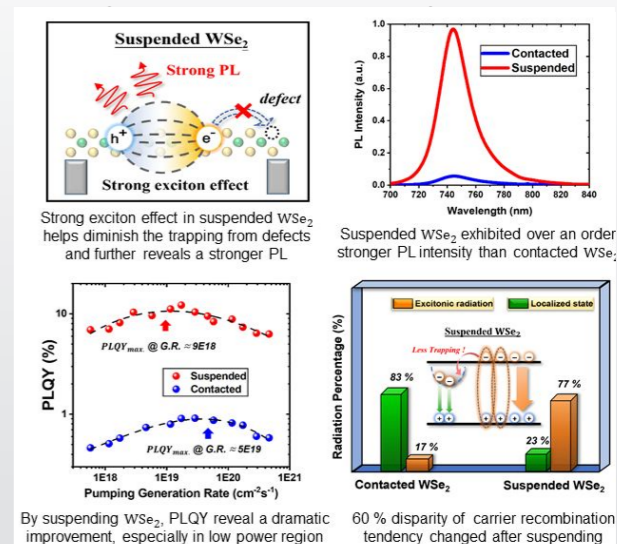
### 研究重點

#### Sustained robust exciton emission in suspended monolayer WSe<sub>2</sub> within the low carrier density regime for quantum emitter applications

Zheng-Zhe Chen, Chiao-Yun Chang, Ya-Ting Tsai, Po-Cheng Tsai, Shih-Yen Lin, and Min-Hsiung Shih\*

Research Center for Applied Sciences (RCAS), Academic Sinica  
APL Materials (2024), DOI: 10.1063/5.0198072

In order to reduce the effect of carrier trapping and sustain a strong photoluminescence (PL) emission under low power pumping conditions, we investigated the influence of "suspending" a monolayer of tungsten diselenide (WSe<sub>2</sub>). Not only PL intensity but also the photoluminescence quantum yield (PLQY) has exhibited a huge, order-scale enhancement through suspending. With its strong excitonic effect, suspended WSe<sub>2</sub> offers a solution to reduce carrier trapping. Moreover, in the low-power range, where SRH recombination dominates, suspended WSe<sub>2</sub> exhibited a remarkably higher percentage of excitonic radiation compared to contacted WSe<sub>2</sub>. Herein, we quantitatively demonstrate the significance of the suspended WSe<sub>2</sub> monolayer in a low carrier density region, highlighting its potential for developing compact, low-power quantum emitters in the future.

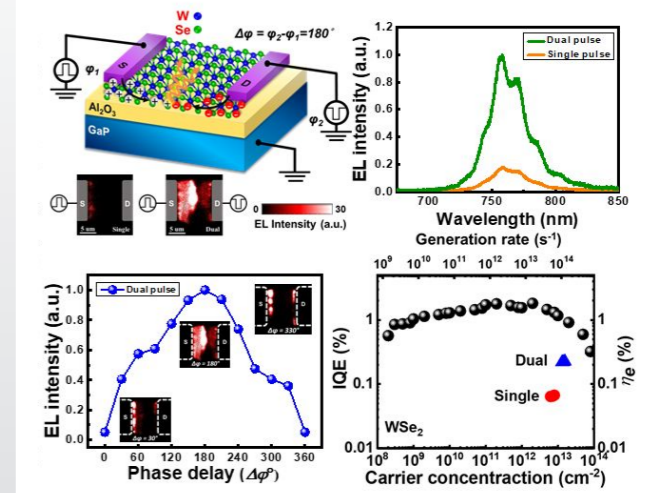


#### Electrical Control of Electroluminescence in 2D Semiconductor Light Emitting Device Through Synchronous Injection of Electrons and Holes

Konthoujam James Singh, Yen-Shou Lin, Zheng-Zhe Chen, Chiao-Yun Chang, Yu-Wei Zhang, Shih-Yen Lin, Der-Hsien Lien, Hao-Chung Kuo, and Min-Hsiung Shih\*

Research Center for Applied Sciences (RCAS), Academic Sinica  
Adv. Mater. Technol. (2025), <https://doi.org/10.1002/admt.202401743>

This study presents a method to enhance charge carrier injection in transition metal dichalcogenide (TMDC)-based light-emitting devices driven by alternating current (AC), utilizing a dual-pulse injection strategy. The dual-pulse configuration results in a significant enhancement of electroluminescence (EL) intensity, achieving approximately a sixfold increase compared to single-pulse operation. Phase delay-dependent EL behavior was observed, with the maximum integrated EL intensity occurring at a 180° phase delay. Furthermore, the dual-pulse device demonstrated an approximate 3.5-fold improvement in external EL efficiency ( $\eta_e$ ) compared to the single-pulse configuration. These findings underscore the potential of controlled carrier recombination in TMDC-based LEDs to advance their performance for applications in display technologies, solid-state lighting, optical communication, and electrically tunable light sources.





# 關肇正

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### 個人簡介

關肇正研究員，從事計算物理和材料研究，特別是奈米電子學和新興材料的計算模擬。他獲得了麥吉爾大學物理學博士學位，並在西北大學化學系當過博士後。

他開發計算模型來了解二維材料與金電極的接觸電阻、磁性薄膜間的非共線層間交換耦合、聚合物保護和提升的鈣鈦礦量子點薄膜、複雜過渡金屬氮化物的電漿子特性。這些研究將幫助奈米電子學、自旋電子學、準固態電池和光子學的發展。他在 2021 與 2022 得到未來科技獎。

他目前指導六名博班研究生，以培養計算奈米電子學領域的人才。他還擔任《Scientific Reports》和《華人物理學報》的編輯，並為中央研究院期刊委員會委員。

他未來的研究旨在透過加強跨學科合作，橋接在奈米電子學和新興材料領域中理論與實驗之間的差距。

### 代表著作

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- 4 G.-W. Peng, H.-C. Wang, Y.-J. Zhong, C.-C. Kaun\*, and C.-H. Chang\*, "Driving noncollinear interlayer exchange coupling intrinsically in magnetic trilayers", Materials Today Physics 48, 101544 (2024).
- 5 M. U. Javed, J.-W. Yang, S. Kumari, M. Mustaqeem, T.-Y. Peng, L. C. Yang, Y.-J. Lu\*, and C.-C. Kaun\*, "Tailoring the plasmonic properties of complex transition metal nitrides: A theoretical and experimental approach", Applied Surface Science 641, 158486 (2023).

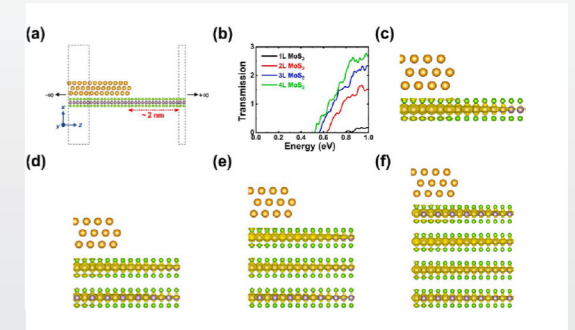
### 研究重點

#### High-Performance Transistors with Polycrystalline 2D Material Channels: The Influence of Gold Electrode Crystallinity and the Layer Number of Molybdenum Disulfide Channels

C.-J. Chang, P.-Z. Huang, K.-B. Lin, T.-H. Chang, W.-C. Tu, C.-C. Kaun\*, and S.-Y. Lin\*

Applied Surface Science, 2025, DOI:10.1016/j.apsusc.2025.162795

Since two Au electrodes of MoS<sub>2</sub> transistors are well-separated in the experiment, only one Au (111)/MoS<sub>2</sub> and MoS<sub>2</sub> interface is considered in our two-probe model (a). The transmission spectra of Au/MoS<sub>2</sub> junctions at V<sub>DS</sub> = 1.0 V show that the quad-layer Au/MoS<sub>2</sub> junction has the largest current and the smallest threshold voltage (b), aligning with our experiment data. The charge densities of Au/MoS<sub>2</sub> junctions at V<sub>DS</sub> = 1.0 V show that the number of effective conduction channel increases as the number of MoS<sub>2</sub> layer increases, however, in a nonlinear fashion (c-f). Whereas the contact resistance is inversely proportional to the effective conduction channel number, it depends on the allocated electron density under the bias voltage.



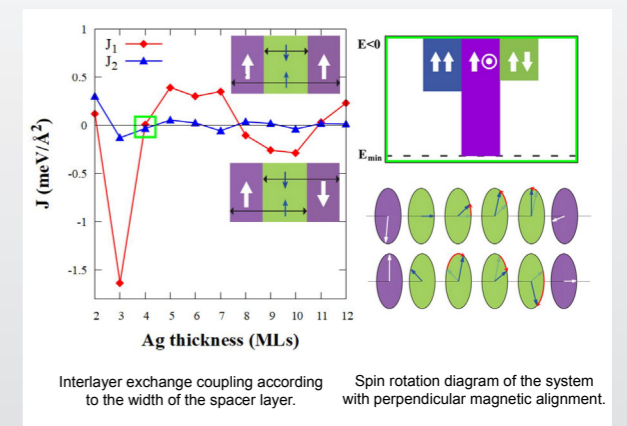
(a) Structure of the two-probe model. (b) Non-equilibrium transmission spectra and (c-f) charge distributions of Au/MoS<sub>2</sub> junctions at V<sub>DS</sub> = 1.0 V with mono-, bi-, tri-, and quad-layer MoS<sub>2</sub>, respectively.

#### Driving noncollinear interlayer exchange coupling intrinsically in magnetic trilayers

G.-W. Peng, H.-C. Wang, Y.-J. Zhong, C.-C. Kaun\*, and C.-H. Chang\*

Materials Today Physics, 2024, DOI:10.1016/j.mtphys.2024.101544

Recent experiments demonstrate that manipulating the width or the nature of conducting spacer induces noncollinear magnetic alignment between the side magnetic layers. Our theoretical analysis reveals that altering the width of spacer significantly affects the interlayer exchange coupling (IEC), resulting in noncollinear alignment. Through analytic and first-principles methods, our study on the Fe/Ag/Fe trilayer shows that at a specific width of the Ag spacer, the magnetic moments of side layers tend to be perpendicular. This alignment is mediated by Ag quantum well states, exhibiting spin spirals across the trilayer. Our results reveal that the noncollinear IEC offers a degree of freedom to control magnetic devices and boot spintronic technology with improved transport capabilities.





# 林時彥

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### 個人簡介

林時彥研究員在 2001 年自國立台灣大學獲得電子電機博士，他目前的研究重心放在於二維材料的成長以及其於電子與光學元件的應用。

林研究員與台積電在二維材料於電子元件的應用長期合作超過十年，他出版了超過 150 篇期刊論文並擁有 15 項美國專利。

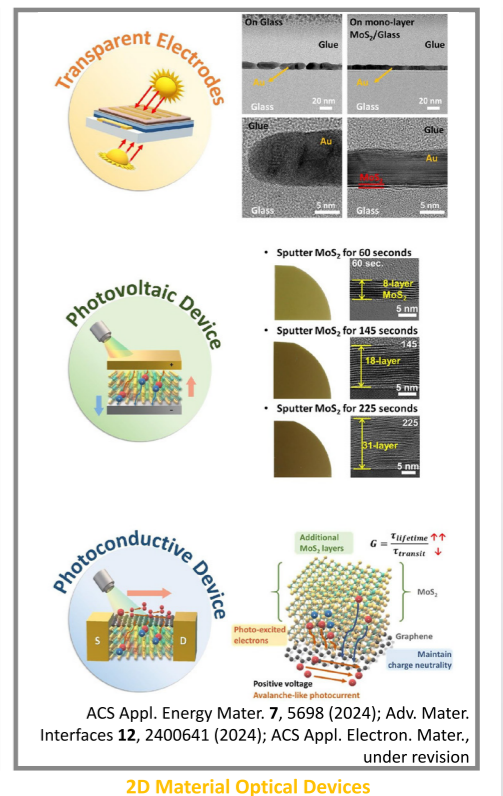
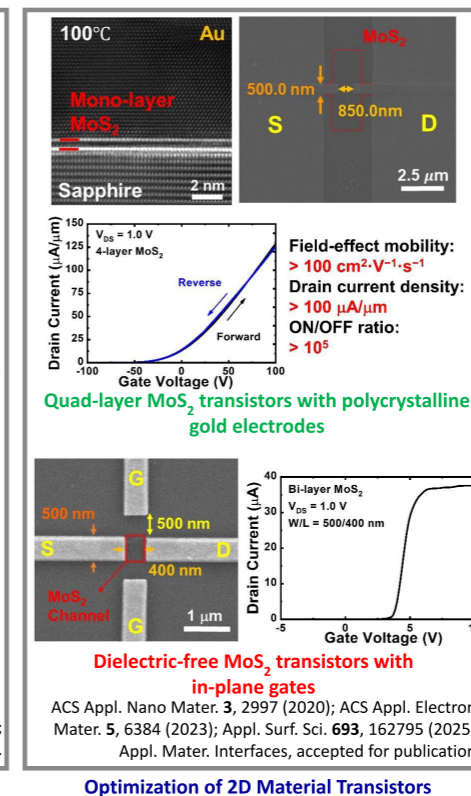
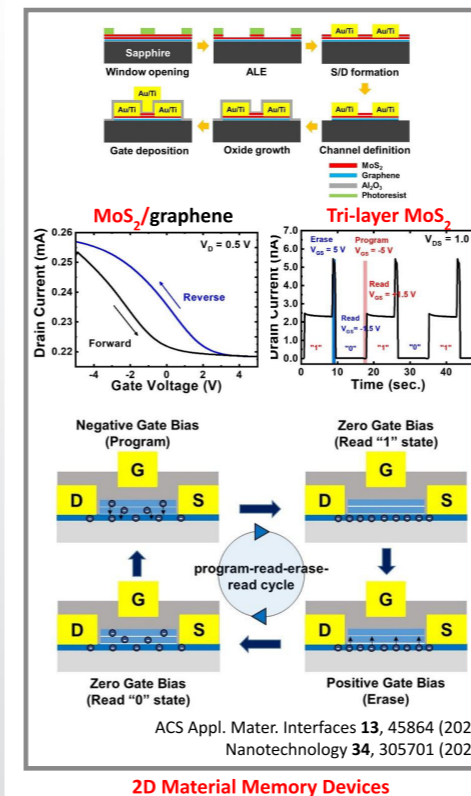
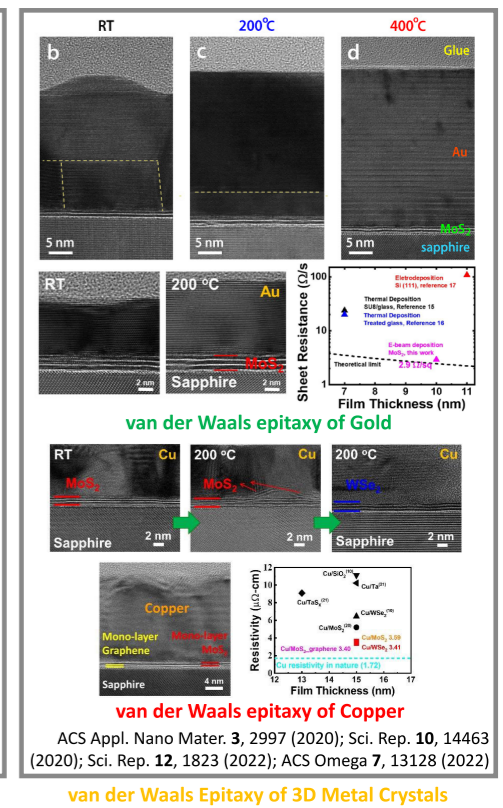
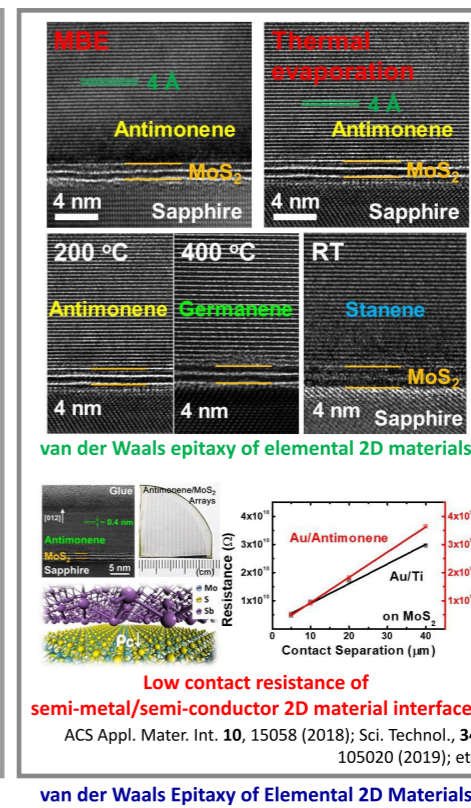
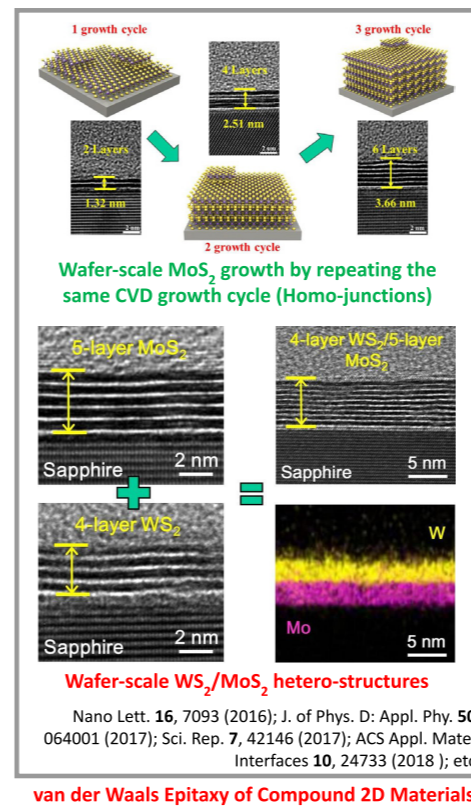
林研究員同時也是台大、成大、東華、暨南以及台東等國立大學的合聘教授，他指導過超過 50 位碩士班學生以及 11 位博士班學生，除了林研究員的個人獎項外，他指導的學生也獲得超過 30 個獎項，林研究員在去年也領導研究團隊獲得 2024 年未來科技獎。

林研究員將會持續專注於以實際應用驅動的研究方向。

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### 研究重點



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## 個人簡介

張書維目前是應用科學研究中心的副研究員，專長為光子學的理论、設計和應用。他的研究興趣主要在具有特異點光子晶體共振腔的手性模態和基於積體光子學或光子晶體之連續束縛態，大多針對具有新穎特徵的雷射。除了這些主要跟元件相關的主題外，他也研究較偏系統導向的經典通訊和量子通訊的積體光子電路。張博士在伊利諾大學厄巴納 - 香檳分校獲得博士學位，並為 RCAS 以及台灣學術或工業單位的多個研究計畫做出了貢獻。

張博士曾經開發了一種以廣義特徵值問題形式呈現且基於電源的頻域方法，用於對一般雷射腔體進行模擬。此方法可以直接且明確地提供腔體的閾值增益、模態體積和偏限因子。這些參數是無法以傳統模態分布的數值積分明確定義。

張書維博士與應科中心的施閔雄博士和林時彥博士合作研究新型半導體雷射和基於二維材料的電子裝置。對於前者，他開發了晶片級的旋光雷射。他還透過陽明交通大學參與了台積電與矽光子方面的共同開發計畫。身為導師，他指導了 2 位碩士、2 位博士和 2 名博士後，並培養了光子學領域的新人才。

張博士未來的研究目標是開發給量子應用之整合光子系統中的主動和被動元件。另外，張博士會較偏向以系統的視角來關注這些應用的實用性。他傾向於在學術發現的新穎性和可行性之間找到平衡，並試圖解決通用系統的關鍵問題或將有用的結果轉化為現實世界的產品。

## 代表著作

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- 4 W. C. Tang, Y. T. Liu, C. H. Yeh, C. H. Lu, C. H. Tu, Y. L. Lin, Y. C. Lin, T. L. Hsu, L. Gao, S. W. Chang, P. Chen, and B. C. Chen\*, "Optogenetic manipulation of cell migration with high spatiotemporal resolution using lattice lightsheet microscopy," *Commun. Biol.*, 5 879 (2022) [DOI: [10.1038/s42003-022-03835-6](https://doi.org/10.1038/s42003-022-03835-6)]
- 5 H. T. Lin, C. Y. Chang, C. L. Yu, A. B. Lee, S. Y. Gu, L. S. Lu, Y. W. Zhang, S. Y. Lin, W. H. Chang, S. W. Chang, and M. H. Shih\*, "Boost lasing performances of 2D semiconductor in a hybrid tungsten diselenide monolayer/cadmium selenide quantum dots microcavity laser," *Adv. Optical Mater.* 2200799 (2022) [DOI: [10.1002/adom.202200799](https://doi.org/10.1002/adom.202200799)]

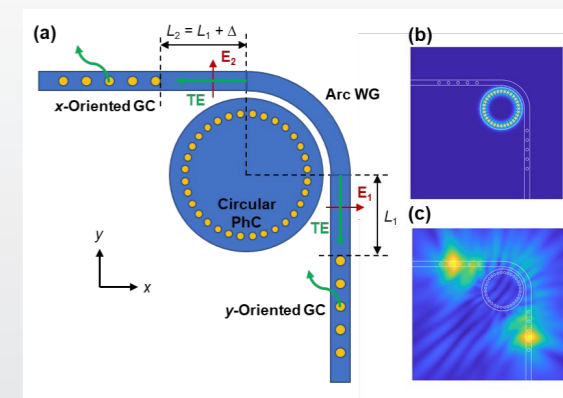
## 研究重點

### Circularly-Polarized Laser Equivalent to Two Phase-Shifted Linearly-Polarized Sources

Jui-Tse Tsai, Chi-Ti Hsieh, Chao-Chieh Cheng, Min-Hsiung Shih, Shu-Wei Chang

Academic Sinica, Research Center for Applied Sciences

The CP light is conventionally generated by passing the linearly-polarized (LP) one through quarter wave plates which are too thick for packed integrations. In this work, the in-plane submicron phase shifter substitutes the quarter-wave plate in the creation of CP light. After the lasing field of a holed microdisk is coupled into the nearby waveguide and phase shifter, it is guided into two grating couplers that output orthogonally LP waves vertically. The two LP waves are phase-shifted by  $\pi/2$  and combine into the coherent CP radiation in the far-field zone. Experimentally, the fabricated devices exhibit a degree of circular polarization as high as 74%. This device scheme is simple and effective in that it relies on no extrinsic materials, large-area auxiliary structures, or specialized operation conditions critical for CP radiation.



The schematic of a microdisk coupled to two linearly-polarized scatters. The output phases of two scattered fields are phase-shifted by segments with different lengths.

The field profiles on the planes inside and on the top of microdisk.

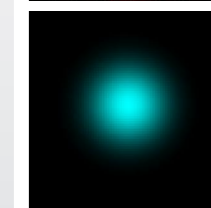
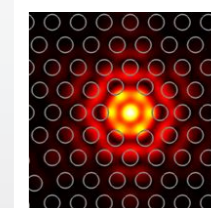
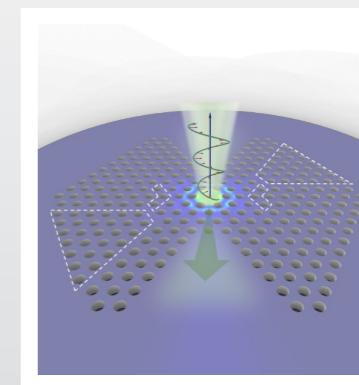
### Spinning Mode with Maximum Chirality in Photonic Crystal Defect Cavity at Exceptional Point

Chao-Chieh Cheng, Pi-Ju Cheng, Tzu-Wei Huang, Wei-Ting Wang, Jui-Tse Tsai, Min-Hsiung Shih, and Shu-Wei Chang

Academic Sinica, Research Center for Applied Sciences

Optical modes spinning with maximum chirality in cavities at chip level are essential for quantum and biomedical applications. The coalescent chiral mode at the exceptional point (EP) due to non-hermicity is the one in demand. In this work, we realize circularly-polarized-like lasing modes with maximum chirality at the EP of photonic-crystal one-hole cavities. We adopt the in-plane tunneling loss that is well controlled with the layer number of air holes in photonic-crystal slab. By removing and relocating holes in blocks, we systematically elevate the chirality of radiation field. The collective variations of holes render the EP robust against the uncertainty in fabrications. Without auxiliary non-Hermitian and chiral structures, our works promote coherent chiral light sources at chip level.

The schematic of non-Hermitian but chiral H1 cavity. Some of air holes are collectively removed or relocated (enclosed in white dashed lines) when approaching the EP.



The near-field and far-field patterns of modes at the chiral exceptional point.

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## 個人簡介

陳祺博士於從美國加州大學爾灣分校取得博士學位，之後在日本理化學研究所 (RIKEN) 進行博士後研究。陳祺博士致力於將原子力顯微鏡 (AFM)，及掃描隧道顯微鏡 (STM) 與光學技術相結合，以近場光學 (SNOM) 解析各種材料在奈米尺度的光譜特性。

陳祺副研究員的研究涵蓋近場光學儀器開發、基礎近場光學原理，以及對各類硬物質 / 軟物質材料的光譜成像與分析。在其研究生涯實現了所有的近場光學模式： $\alpha$ -SNOM、s-SNOM、STM-EL、和 TERS，而且都達到歷來文獻中數一數二的光學解析度，以及超高品質的近場光學影像。

自 2013 年在應科中心任職以來，陳祺實驗室成功開發水平式的 SNOM 儀器，從自製 AFM 加上全套可移動式顯微鏡光路系統，又發展了自製近場探針的製程，至今在大氣環境、氮氣手套箱、及水中有三套穩定度極佳的完整近場光學系統，均可成功實現近場螢光和近場吸收光譜和影像，成為研究二維材料的激子性質和奈米材料光譜研究的強大工具。

近來，陳祺也在 AFM 和 SNOM 儀器上加入電路，除了量測各種材料微觀的導電特性，更是專注於電致放光和局域光電流成像，希望延伸近場光學結合電性來研究各種低維度材料的微觀光電轉換。

## 代表著作

- 1 P.-W. Tang, S.-Y. Shiau, H.-C. Chou, J.-R. Yu, X.-Q. Zhang, C.-T. Sung, Y.-H. Lee\*, and C. Chen\* Visualization of bandgap evolution and bilayer coupling in  $W_xMo_{1-x}S_2$  alloy by near-field broadband absorption microscopy. *ACS Nano*, **16**, 5, 7503–7511(2022)
- 2 H.-C. Chou, X.-Q. Zhang, S.-Y. Shiau, C.-H. Chien, P.-W. Tang, C.-T. Sung, Y.-C. Chang, Y.-H. Lee\*, and C. C. Chen\* Near-Field Spectroscopic Imaging of Exciton Quenching at the Atomically Sharp  $MoS_2/WS_2$  Lateral Heterojunction. *Nanoscale* **14**, 6323 – 6330 (2022)
- 3 S. Luo, P. P. Lin, L.-Y. Nieh, G.-B. Liao, P.-W. Tang, C. Chen, and J. C. Liao\* A cell-free self-replenishing  $CO_2$  fixing system. *Nature Catalysis* **5**, 154–162 (2022)
- 4 H.-C. Chou, C.-K. Fang, P.-Y. Chung, J.-R. Yu, W.-S. Liao, S.-H. Chen, P. Chen, I.-S. Hwang, J.-T. Chen\*, and C. Chen\* Structural and Optical Identification of Planar Side-Chains Stacking P3HT Nanowires. *Macromolecules* **54**, 23, 10750–10757 (2021)
- 5 J.-R. Yu, H.-C. Chou, C.-W. Yang, W.-S. Liao, I.-S. Hwang, and Chi. Chen\* A Horizontal-type Scanning Near-Field Optical Microscope with Torsional Mode Operation Toward High-Resolution and Non-destructive Imaging of Soft Materials. *Rev. Sci. Instrum.* **91**, 073703 (2020)

## 研究重點

### Scanning Near-Field Optical Microscopy in Various Environments for Nanoscale Molecular and 2D Material Assemblies

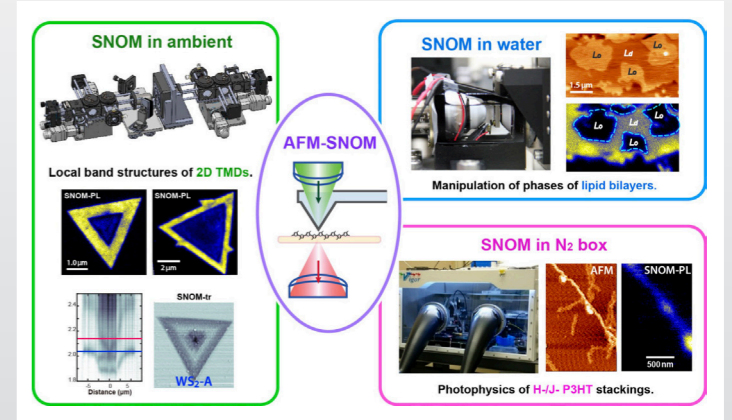
J.-R. Yu, S.-Y. Weng, S.-M. Lai, H.-C. Chou, P.-W. Tang, and Chi Chen\*

P.-W. Tang *et al.*, *ACS Nano*, **16**, 5, 7503 (2022)  
H.-C. Chou *et al.*, *Nanoscale* **14**, 6323 (2022)

H.-C. Chou *et al.*, *Macromolecules* **54**, 10750 (2021)  
J.-R. Yu *et al.*, *Rev. Sci. Instrum.* **91**, 073703(2020)

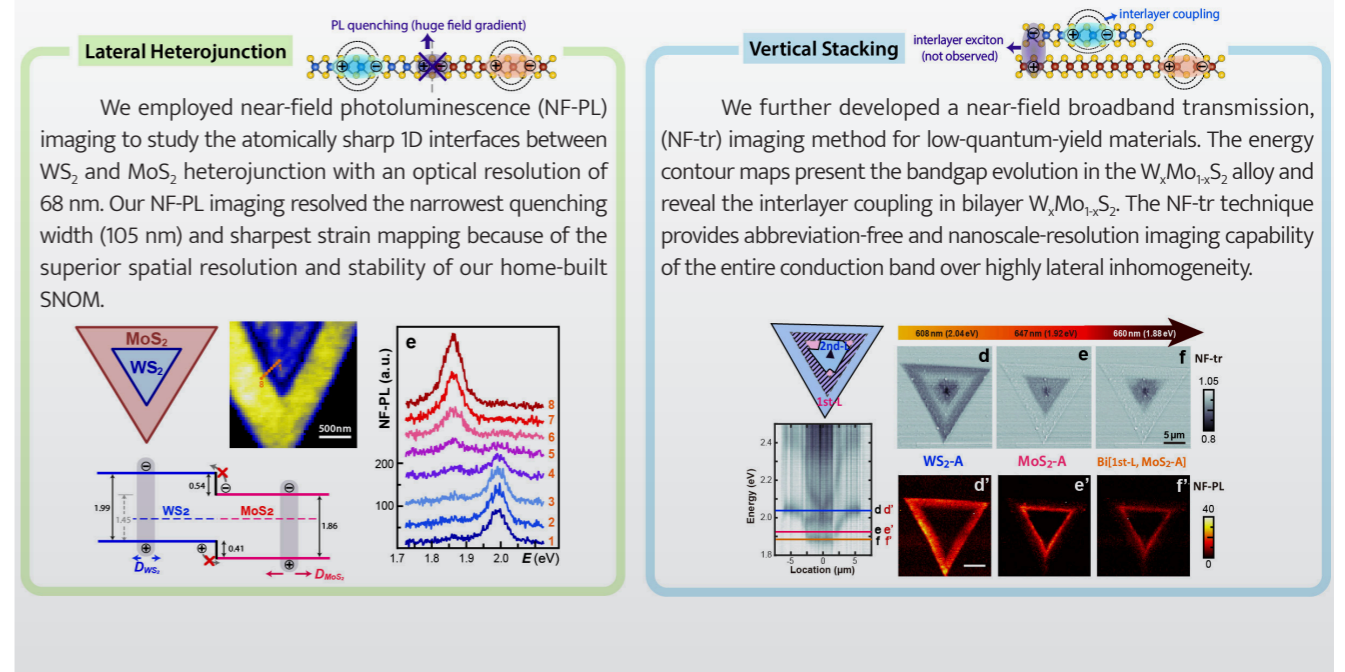
The primary tool developed in my lab is the home-built AFM-based scanning near-field optical microscopy (SNOM) with spectroscopic readout. Three horizontal-type aperture SNOM instruments in different environments have been successfully constructed and operated to investigate the stacking of 2D materials as well as soft molecular assemblies including polymer nanowires and lipid bilayers.

The SNOM instruments are highly-stable for reproducible topographic scan and optical signaling, which realized high-quality near-field absorption and PL microscopy. We also achieved small amplitude ( $< 2$  nm) tapping mode in glove box and in water to avoid sample damages and to regulate tip-sample interaction. In addition, we have the full control of the near-field tip, including its design, fabrication, and operation.



### Revealing the Local Band Structures of $WS_2/MoS_2$ Heterojunction $W_xMo_{1-x}S_2$ Alloy by Near-Field Optical Imaging

P.-W. Tang, H.-C. Chou, S.-Y. Shiau, J.-R. Yu, X.-Q. Zhang, Y.-H. Lee\*, and Chi Chen\* (RCAS & NTHU)





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### 個人簡介

陳俞辰助研究員，他的專長是研究單個自旋缺陷量子特性與其量子應用。他主要的研究興趣為製作寬能隙材料中的單個自旋缺陷並量測其量子特性，例如鑽石或碳化矽。他在國立清華大學取得碩士學位，之後於英國的牛津大學取得他的博士學位。

他開發了使用飛秒脈衝雷射在鑽石中生成單一個 Nitrogen-vacancy 量子缺陷，並且此方法被證明可以在基質材料中產生最少量的缺陷。因此，雷射生成的 Nitrogen-vacancy 的自旋與光學同調性可以達到其物理極限。並且，他也證明雷射寫入方法可以用於生其他量子缺陷，例如碳化矽中的 silicon vacancy。

他的未來研究方向主要聚焦於兩個主題。第一個主題是在具工業規模製作光子結構的材料中尋找新的自旋量子缺陷，例如二氧化矽或是氮化矽。如此一來，就可以把量子缺陷耦合進 on-chip 光子元件，進而達成可擴展的量子元件。第二個主題是聚焦於製作高品質的具通訊波段螢光的自旋量子缺陷。此種量子缺陷在量子通訊應用上具有極大的潛力。

### 代表著作

- 1 Y. C. Chen, S. C. Lin, J. P. Chou, Y. C. Tsai, C. T. Huang, C. J. Lee, W. H. Chang. Stable Single Photon Emitters with Large Debye–Waller Factor in Silica. ACS Photonics 12, 3, 1461–1469 (2025).
- 2 N. Chejanovsky, A. Mukherjee\*, J. Geng, Y. C. Chen, Y. Kim, A. Denisenko. A. Finkler, T. Taniguchi, K. Watanabe, D. B. R. Dasari\*. P. Auburger, A. Gali, J. H. Smet, and J. Wrachtrup. Single-spin resonance in a van der Waals embedded paramagnetic defect. Nature Materials 20, 1079-1084 (2021).
- 3 M. Niethammer\*, M. Widmann, T. Rendler, N. Morioka, Y. C. Chen, R. Stöhr, J. Ul Hassan, S. Onoda, T. Ohshima, S. Y. Lee, A. Mukherjee, J. Isoya, N. T. Son, and J. Wrachtrup. Coherent electrical readout of defect spins in silicon carbide by photo-ionization at ambient conditions. Nature Communications 10, 5569 (2019).
- 4 C. J. Stephen, B. L. Green, Y. N. D. Lekhai, L. Weng, P. Hill, S. Johnson, A. C. Frangeskou, P. L. Diggle, Y. C. Chen, J. Strain, E. Gu, M. E. Newton, J. M. Smith, P. S. Slater, and G. W. Morley\*. Deep three-dimensional solid-state qubit arrays with long-live spin coherence. Physical Review Applied 12, 064005 (2019).
- 5 M. Widmann\*, M. Niethammer, D. Y. Fedyanin, I. A. Khramtsov, T. Rendler, I. D. Booker, J. Ul Hassan, N. Morioka, Y. C. Chen, I. G. Ivanov, N. T. Son, T. Ohshima, M. Bockstedte, A. Gali, C. Bonato, S. Y. Lee\*, and J. Wrachtrup. Electrical charge state manipulation of single silicon vacancies in a silicon carbide quantum optoelectronic device. Nano Letters 19, 10, 7173-7180 (2019).

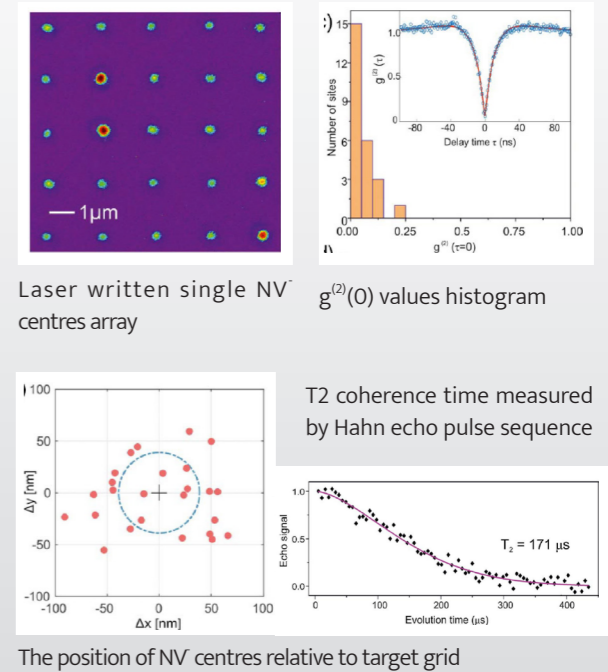
### 研究重點

## Laser writing of individual nitrogen-vacancy defects in diamond with near-unity yield

Yu-Chen Chen

Optica 6 (2019): 662-667

Spin defects in wide band gap materials show a great potential for various quantum applications. Nitrogen-vacancy (NV) centre in diamond is one of the most promising spin defect. In order to realise quantum applications, it is important to engineer the NV centre at desired location with high positioning accuracy and yield. Although the traditional single NV centre generation method can provide high position accuracy, the yield is lower than 50%. We developed a method which using femtosecond laser pulse sequence combined with fluorescence feedback to generate single NV centres array with yield of 96%. The positioning accuracy of single NV centres in the image plane is measured to be about 40 nm. Moreover, the laser written single NV centres still possess good spin coherence properties and the  $T_2$  coherence time was measured up to 170  $\mu$ s by standard Hahn echo measurements.

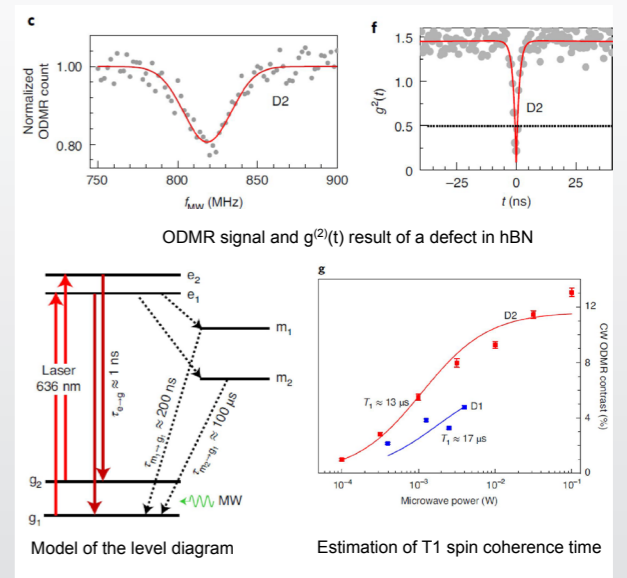


## Spin readout and manipulation of single defect in hBN 2D material

Yu-Chen Chen

Nature Materials 20 (2021): 1079-1084

Single photon emitters in hexagonal boron nitride (hBN) have attracted many researchers' attentions, because it can be easily coupled into photonic structures. Moreover, some single photon emitters' zero-phonon line (ZPL) have been found to be Fourier transformed limited linewidth at room temperature. This property pave a way to realise the quantum repeater and quantum communication at room temperature. However, single spin defects was not discovered in the hBN. We have successfully found that some single defects show optically detected magnetic resonance (ODMR). Various laser and microwave pulse sequences were used to investigate the spin dynamics and we built a simple model to describe the results. We concluded that the magnetic resonance locates at the ground state. The g-factor of the defect was measured to be 2.06. The  $T_1$  spin coherence time of the spin defects were estimated to be around 13~17  $\mu$ s.



# 重要獎項榮譽

2025	包淳偉	國科會傑出研究獎
	呂宥蓉	iSPN 年輕學者獎, Singapore
2024	呂宥蓉 林時彥	國科會未來科技獎
	郭宗枋	Fellow of OPTICA
	楊富量	第二十一屆國家新創獎
	魏培坤	第二十一屆國家新創獎
2023	方牧懷	中央研究院前瞻計畫
	包淳偉	有庠科技論文獎
	呂宥蓉	國際光電工程學會 SPIE Senior Members, USA
2022	包淳偉	中研院深耕計畫
	朱治偉	全球頂尖 2% 科學家
	朱治偉	國際光學工程 (SPIE) 資深會員
	林鈺容	國科會補助 2030 跨世代年輕學者方案 - 新秀學者計畫
	陳 祺	中央研究院前瞻計畫
	董奕鍾	Scientist with Top 2% Single Year Impact
	楊富量	第十九屆國家新創獎
	謝東翰	第十九屆國家新創獎
	關肇正	國科會未來科技獎
	2021	呂宥蓉
施閔雄		2021 International Electron Devices & Materials Symposium (IEDMS), 論文獎
施閔雄		2021 Optics & Photonics Taiwan International Conference (OPTIC), 論文獎
陳培菱		中研院深耕計畫
陳壁彰		中央研究院年輕學者研究成果獎
魏培坤		中研院特優學術研究獎
關肇正		科技部未來科技獎
2020	呂宥蓉	中華民國光電學會青年光電工程獎
	林鈺容	財團法人李昭仁教授生醫工程發展基金會年輕學者獎
	郭宗枋	Fellow of SPIE
	陳壁彰	2020 第十八屆有庠科技論文獎 - 光電組
	郭志禹	中華水土保持學會論文獎
	楊富量	第十七屆國家新創獎

# 中心核心設施

本中心核心設施是為提供本中心及本院研究同仁進行研究使用，分布在跨領域大樓六樓、四樓及地下二樓，目前中心內核心設施依功能可分為三大類型：高解析顯微鏡、樣品分析及微奈米製程（如下圖表一）。

表一、核心設施資訊

類型	儀器	功能	廠牌	位置
高解析顯微鏡	最小光子通量定位顯微鏡	細胞影像分析	Abberior	跨領域 6B06
	原子力顯微鏡	材料表面分析	Bruker DM-CAFM	交大田家炳中心 506 室
	快速雷射掃描共軛焦分光光譜顯微鏡	生物暨螢光樣品量測	Leica TCS-SP5	跨領域 4B20
	液相原子力顯微鏡	奈米材料或元件液態檢測	JPK Nano Wizard II & III	跨領域 B2C01
	顯微拉曼光譜儀	材料螢光及結晶特性分析	Jobin Yvon HR800	跨領域 6B08
	場發射高低真空高解析度掃描式電子顯微鏡	表面結構與元素分析	Nova 200 NPE 44/D8187	跨領域 4C05
	樣品分析	X 光光電子光譜儀	表面與縱深元素分析	ULVAC-PHI PHI-5000 Versaprobe
掃描式離子顯微鏡		表面與縱深元素與分子分析	ULVAC-PAI TRIFTV	跨領域 4C05
皮秒時間相關單分子螢光顯微光譜儀		多通道的時間解析光譜系統	PicoQuant Micro Time 2000	跨領域 6B10
奈米級雷射非接觸式 3D 表面量測儀		奈米級表面輪廓 / 粗糙度量測	Keyence VK9710K S/N 2190011	跨領域 4C01
微米製程	試片準備機一套	表面薄膜製程與蝕刻	Gated Sted SKE104005	跨領域 6A02
	高解析高精度雙束聚焦離子系統	奈米元件結構製作	FEI NanoLab660	跨領域 4B19
	電感耦合電漿蝕刻機	奈米元件乾溼蝕刻	OXFORD ICP65	跨領域 B2C02
	桌上型直寫曝光系統	元件光阻圖樣製作	Heidelberg uPG501	跨領域 B2C02
	奈米壓印曝光機	元件光阻圖樣製作	EVG620 NT	跨領域 B2C02

# 行政人員

本中心的核心設備主要能協助同仁進行生醫影像觀測、材料表面分析、元件結構製作及精密樣品製程等研究；除了核心設施，中心在六樓、四樓及地下二樓都有公用實驗室，配合同仁進行相關製程、影像、細胞及蛋白質研究。

使用者具備本院實驗安全認證後，皆可經由儀器訓練取得核心設施的使用權限，不過具有毒性、揮發性、爆炸性的化學物質不得使用，生物樣品則須於使用記錄備註，磁性及粉體樣品則由管理人員同意才能進行；所有設施使用皆須經由預約 (<http://scheduler.rcas.sinica.edu.tw/>)，並且填寫使用記錄。

所有設施每年都會進行例行性維護保養，本中心也會視情況進行設施升級及相關實驗室配置改善，為了讓同仁安全地進行研究，中心對於各實驗室及設施都有相對應的安全規劃及管理。



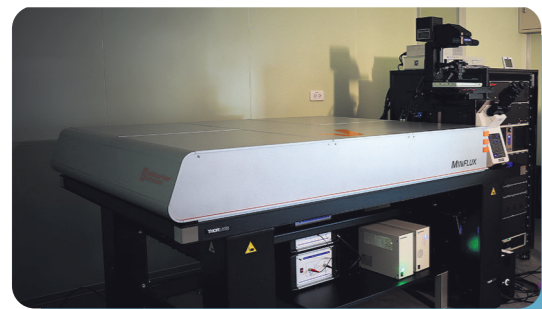
試片準備機一套

Specimen Preparation Equipment



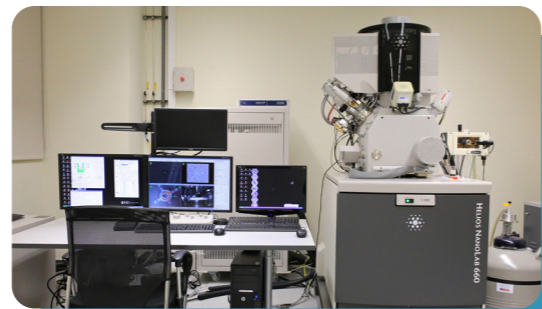
電感耦合電漿蝕刻機

Inductively Coupled Plasma etching system



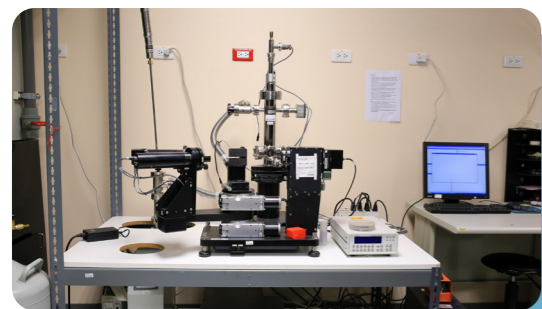
MINIFLUX (最小光子通量定位顯微鏡)

MINIFLUX (MINimal photon FLUXes)



高解析高精度雙束聚焦離子系統

Focus Ion Beam



可變角度陀螺儀

Variable angle spectroscopic ellipsometer



奈米及雷射非接觸式 3D 表面量測儀

Color 3D Laser Scanning Microscope



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